

Attachment 2

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 20

Extended Power Uprate – Meeting on Steam Dryer Analysis

Meeting Presentation Slides

NON-PRORIETARY

Total number of pages in Attachment 2
(excluding this cover sheet) is 99.



Entergy VY Power Upgrade Project

Steam Dryer Updated Analysis Presentation

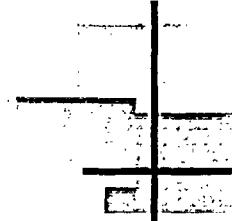
September 29, 2004
Entergy, GE, SIA, CDI, Fluent



Brief Synopsis – Vermont Yankee Power Upgrade

- December 2001 – Start Project
- September 2003 – Submittal
- Extensive Analyses/ Review
- Extensive Plant Modifications

➤ **Operate Safely and Efficiently
Now and in the Future**

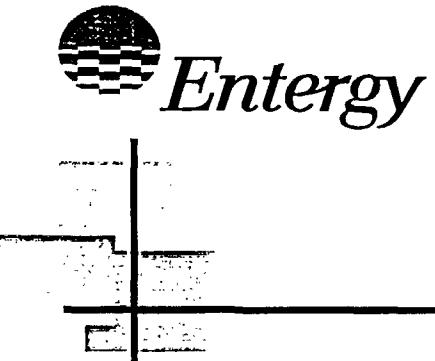


Key Principles

- Reasonable assurance that VY shall operate safely and efficiently at uprated conditions
- VY Steam Dryer shall perform well at EPU and shall NOT challenge system functions important to safety

Industry Operating Experience

- Multiple failures at Quad Cities
 - 'Conventional Wisdom' significantly challenged
 - Critical differences exist between plants
-
- Major evolution of GE methodology
 - Plant-specific approach needed



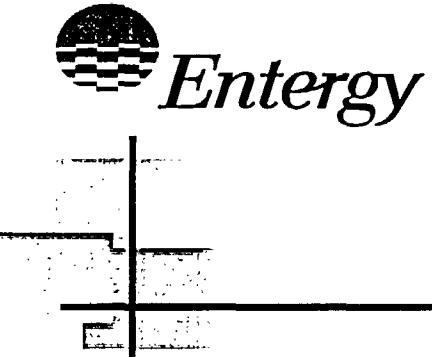
Methodologies

- GE Methodology
 - Generic Load Definition
 - Response Spectrum Analysis
 - Finite Element Model
- Plant-specific Approach
 - Plant Specific Data
 - Acoustic Circuit Model
 - Vortex Shedding CFD Model



Key Safety and Reliability Principles Requirements

- Plant-specific approach to Steam Dryer Issue
- Deliberate, controlled, rigorous power ascension with plateaus
- Rigorous inspection plan: ~8 months of EPU Operation
- Closely follow industry initiatives



Presentation Overview

- Open session
 - VY dryer analysis changes summary:
 - ◆ Plant-specific load definition
 - ◆ Updated VY dryer analysis results
 - Vortex Shedding investigation
 - Results and comparisons
 - Power Ascension/ Dryer monitoring plan summary

Presentation Overview (cont.)

- Closed session
 - Detailed presentations:
 - ◆ VY acoustic loads analysis
 - ◆ VY plant specific load definition
 - ◆ Comparison VY FIV measurements
 - ◆ Dryer power ascension monitoring plan



Dryer Analysis Changes Summary

- VY plant-specific load definition
 - Acoustic Model Developed (CDI)
 - Plant Specific Main Steam Instrument Data Obtained
 - Data converted to Main Steam Pressures
 - Dryer Load Definition created
 - GE Response Spectrum Developed
 - GE Finite Element Model Run
 - Results

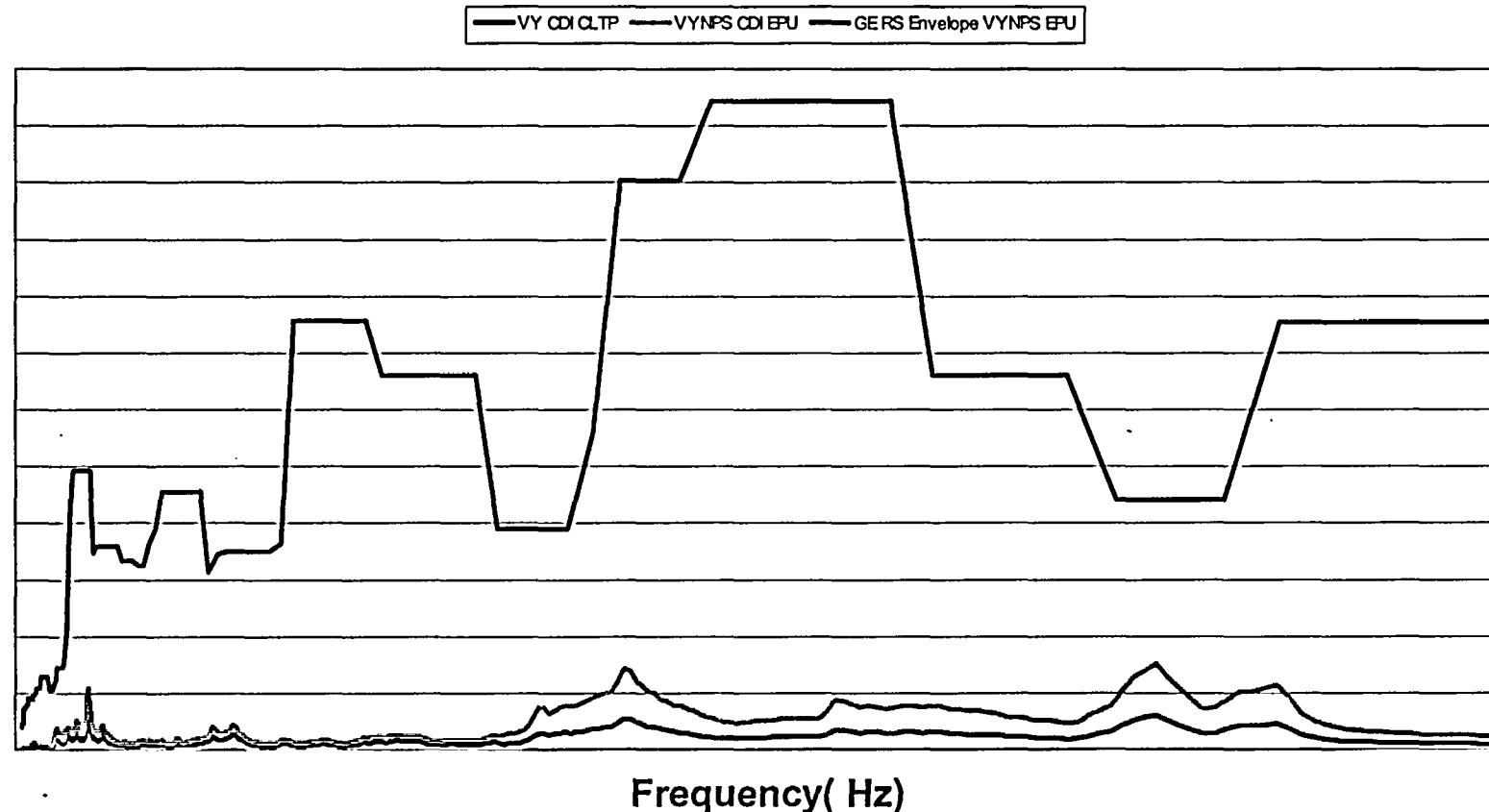


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Dryer Analysis Changes Summary

(cont)

VY plant specific load definition

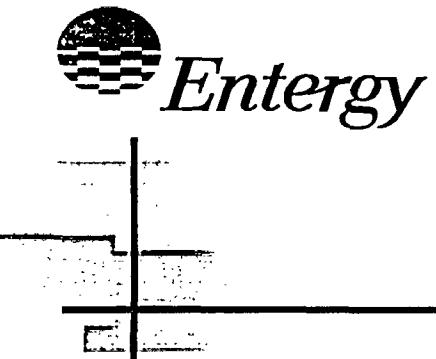


Dryer Analysis Changes Summary (cont)

- Analysis stress results:
 - All dryer components evaluated in finite element analysis at EPU were less than fatigue stress criteria

Vortex Shedding Investigation

- Question on impact/role of vortex shedding
- CFD Model developed of VY Vessel/Dryer (Fluent)
 - Industry accepted methodology
 - New application
- Initial results
 - Low Frequency loads
 - Consistent with acoustic model frequencies

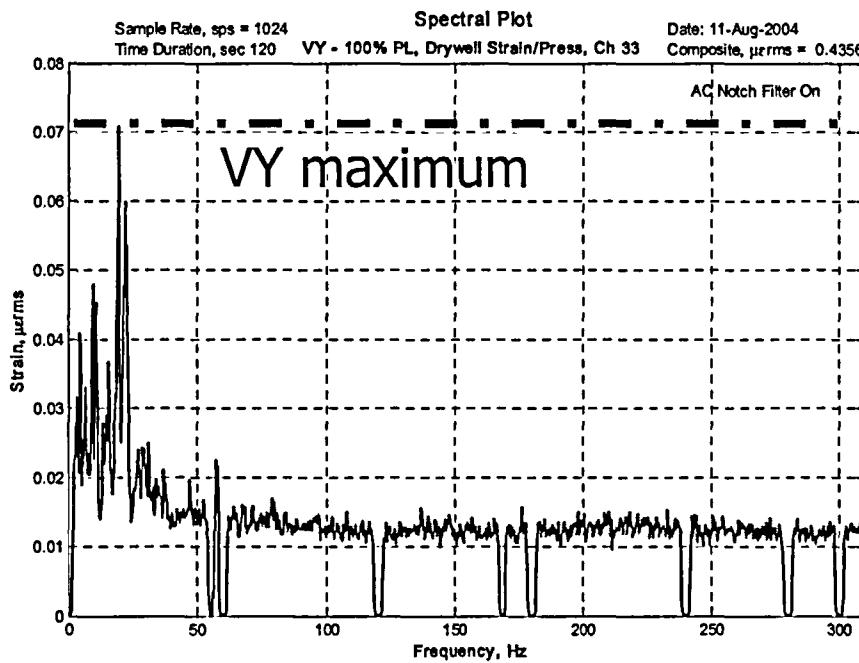


VY FIV Comparison

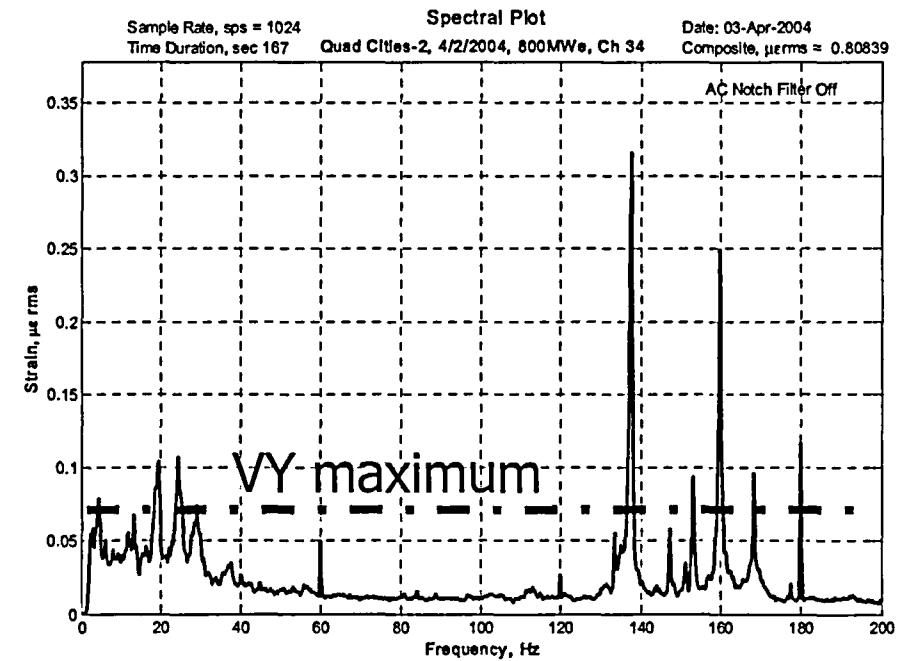
- Strain Gauge Data – VY vs. QC (OLTP)
- Piping Vibration Levels

VY FIV Comparison

VY vs. QC2 100% OLTP Strain Measurements



Vermont Yankee

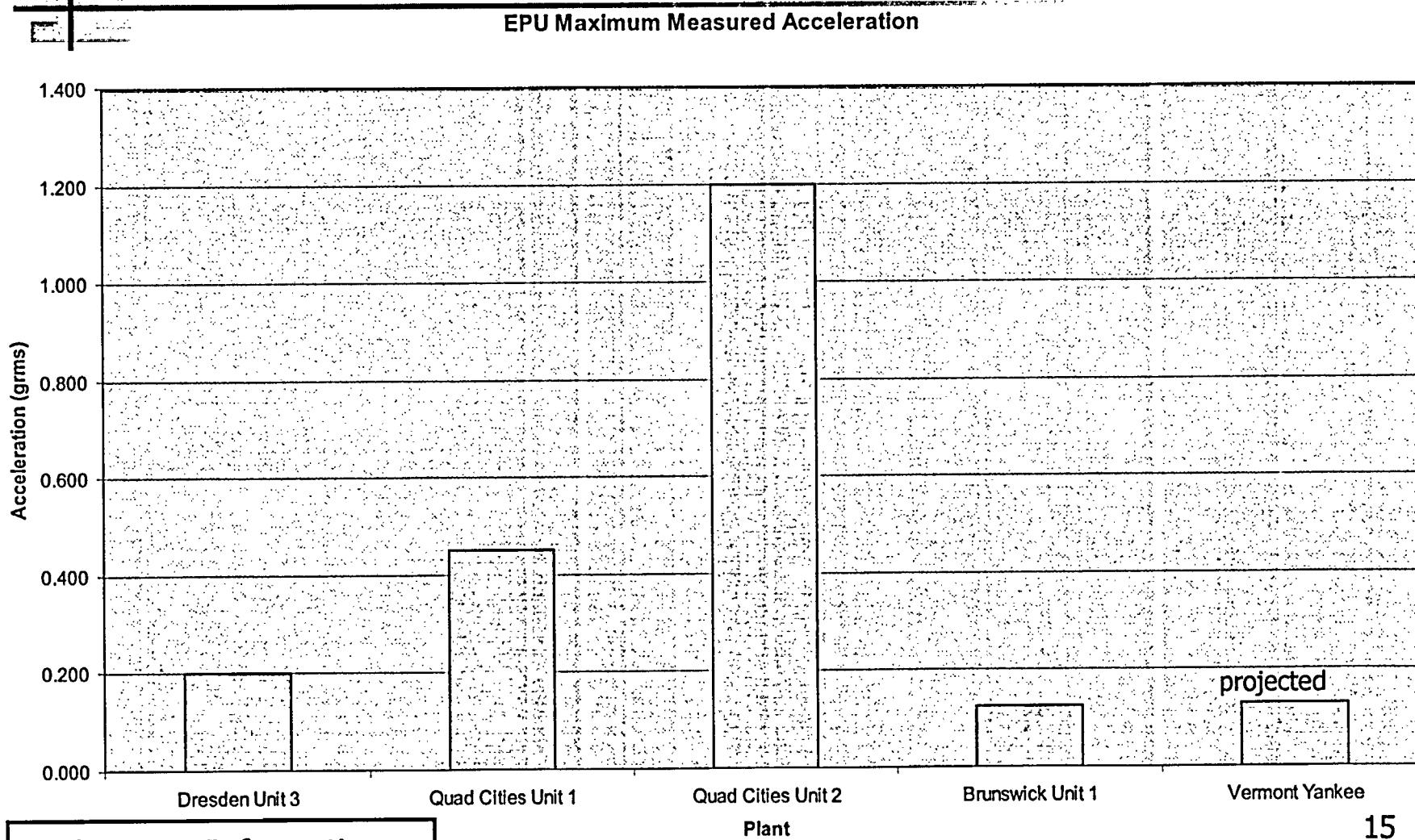


Quad Cities Unit 2



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VY FIV Comparison



Dryer FIV Monitoring Plan Summary

- Objective

- Ensure dryer integrity during gradual power increase

- Approach

- Take plant data at ~ 2.5% power increments
 - Hold at 5% incremental power levels for 7 days (minimum)
 - Compare data to acceptance criteria
 - Moisture carryover monitoring (daily)

- Dryer Inspection

- First Stage of Uprate 115% OLTP Maximum
 - Planned Refuel Outage/inspection ~8 months after uprate

VY Plant-Specific Load Definition [afternoon]

- Presentation of methods and results
 - Acoustic circuit analysis
 - CFD (methods)
 - Strain gauge measurements
- VY plant-specific dryer load definition

VY - Acoustic Loads Analysis

- Purpose: determine acoustic load contribution
- Analytical model using measured plant data
- Analysis has been independently reviewed

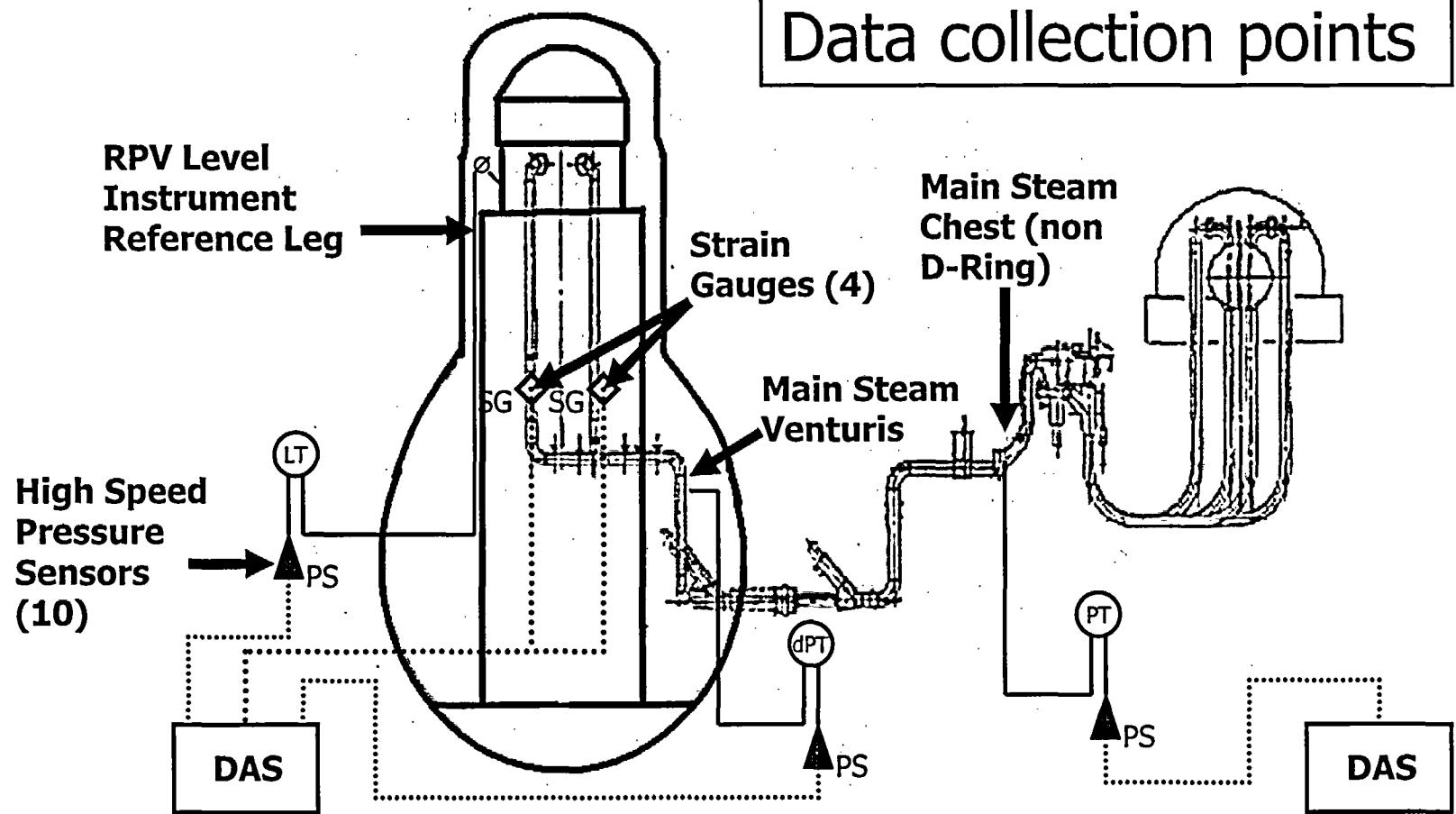
VY - Acoustic Loads Analysis (cont.)

- Plant-specific data collection
 - VY pressure data taken at:
 - ◆ MSL venturis (one on each steamline)
 - ◆ Vessel instrument reference legs (2)
 - ◆ Main steam header (one on each steamline)



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VY - Acoustic Loads Analysis (cont.)



VY - Acoustic Loads Analysis (cont.)

- Plant-specific data collection (cont.)
 - VY strain gauge data taken at:
 - ◆ MSL, vertical run close to RPV (one on each steamline)
 - ◆ Repeatability confirmed

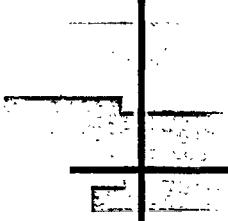
VY - Acoustic Loads Analysis (cont.)

- Plant-specific data collection (cont.)

- Sampling rate \geq 1024 samples/sec
- Data taken at 80%, 85%, 90%, 92%, 95%, 96% and 100% power
- Data taken for 20 to 120 second periods
 - ◆ Statistically significant sample



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VY - Acoustic Load Definition

- Acoustic circuit model:

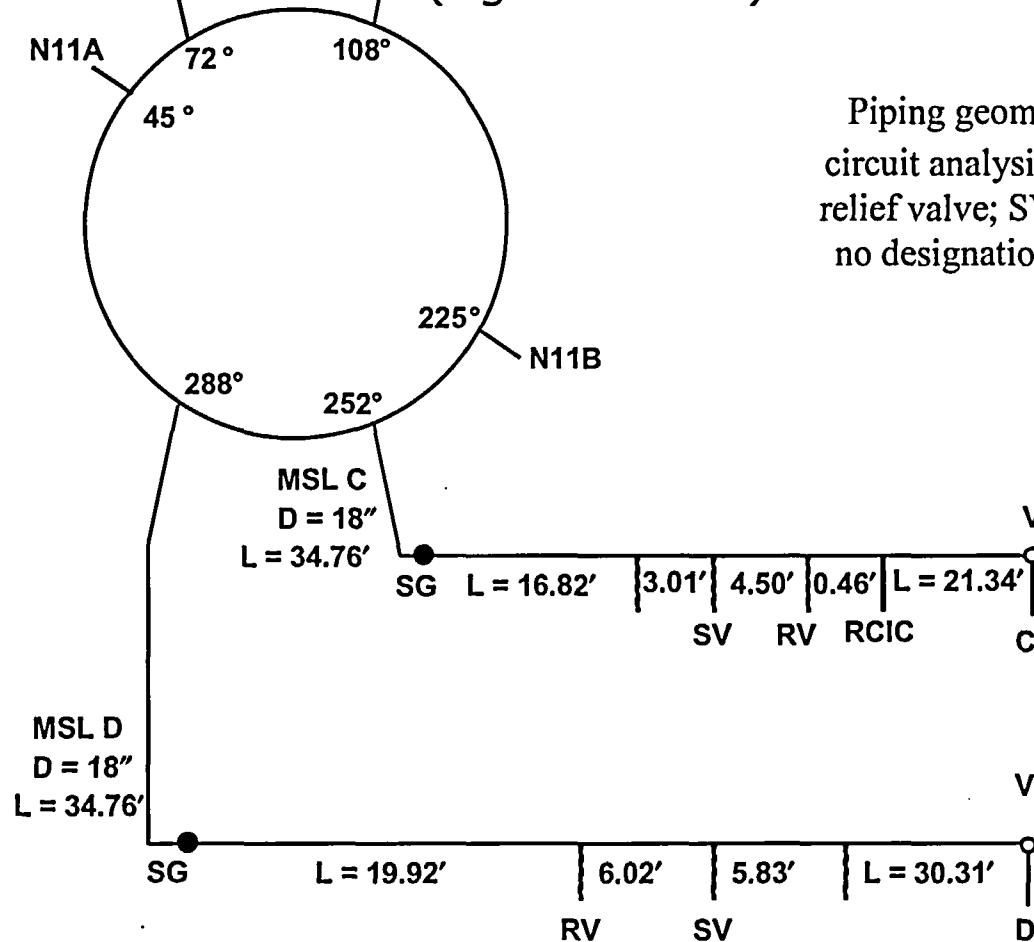
- VY dryer dimensions
- VY main steam system dimensions



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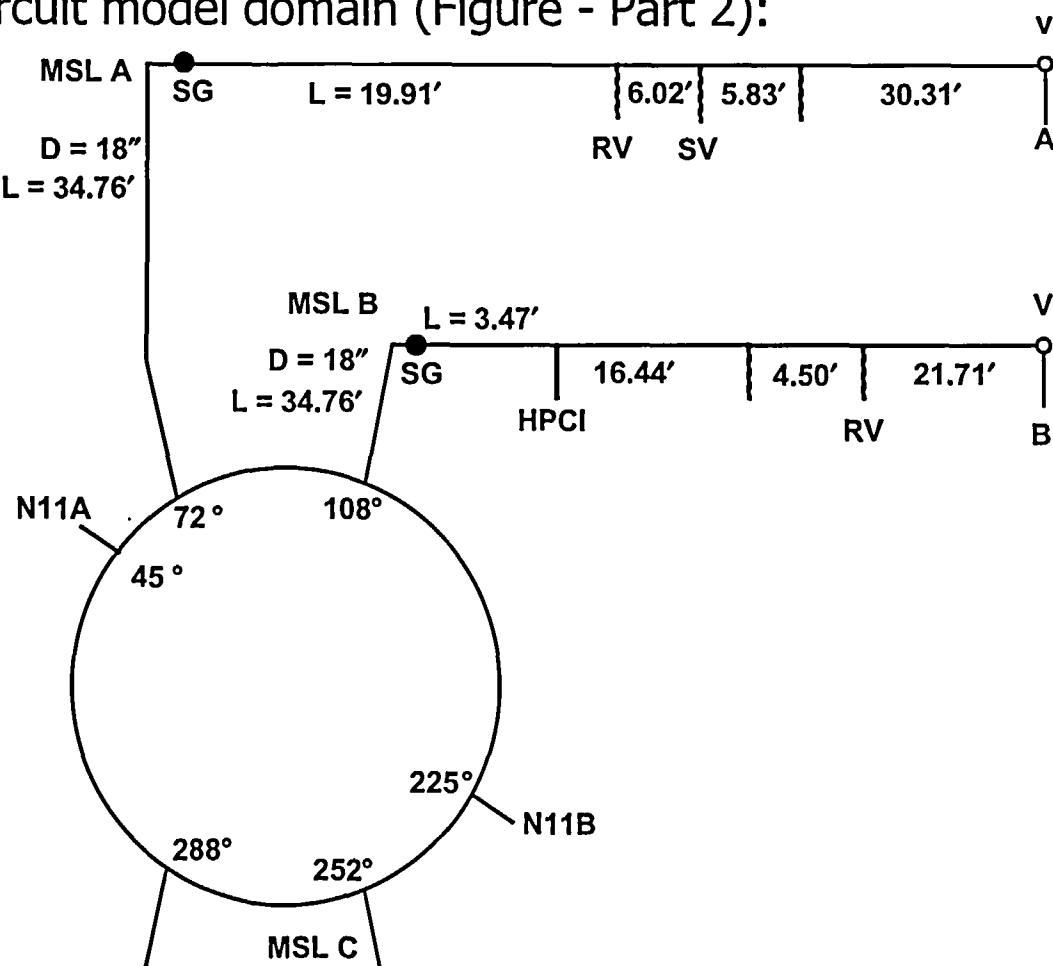
VY - Acoustic Load Definition (cont.)

- Acoustic circuit model domain (Figure - Part 1):



VY - Acoustic Load Definition (cont.)

- Acoustic circuit model domain (Figure - Part 2):

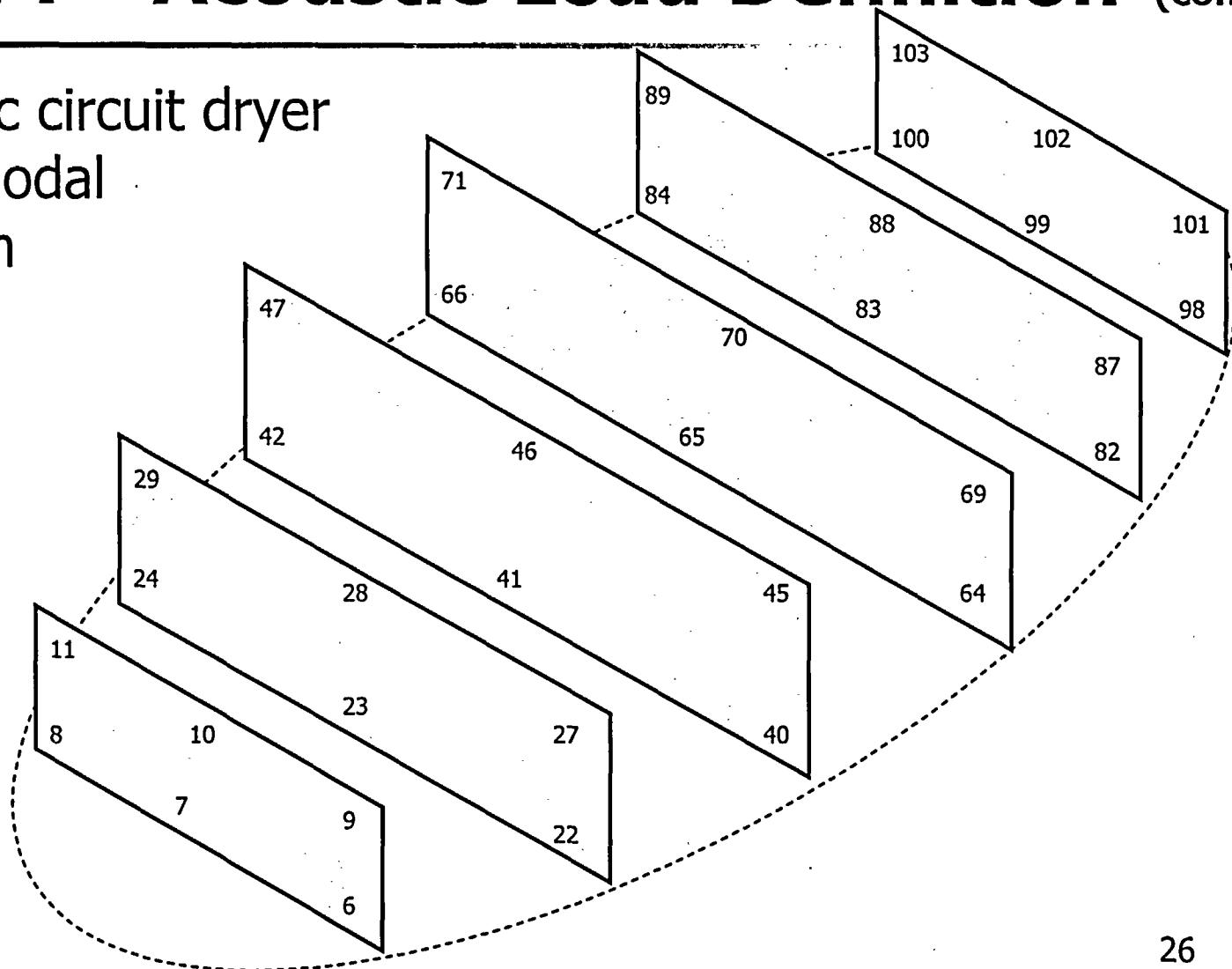




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VY - Acoustic Load Definition (cont.)

Acoustic circuit dryer
baffle nodal
diagram

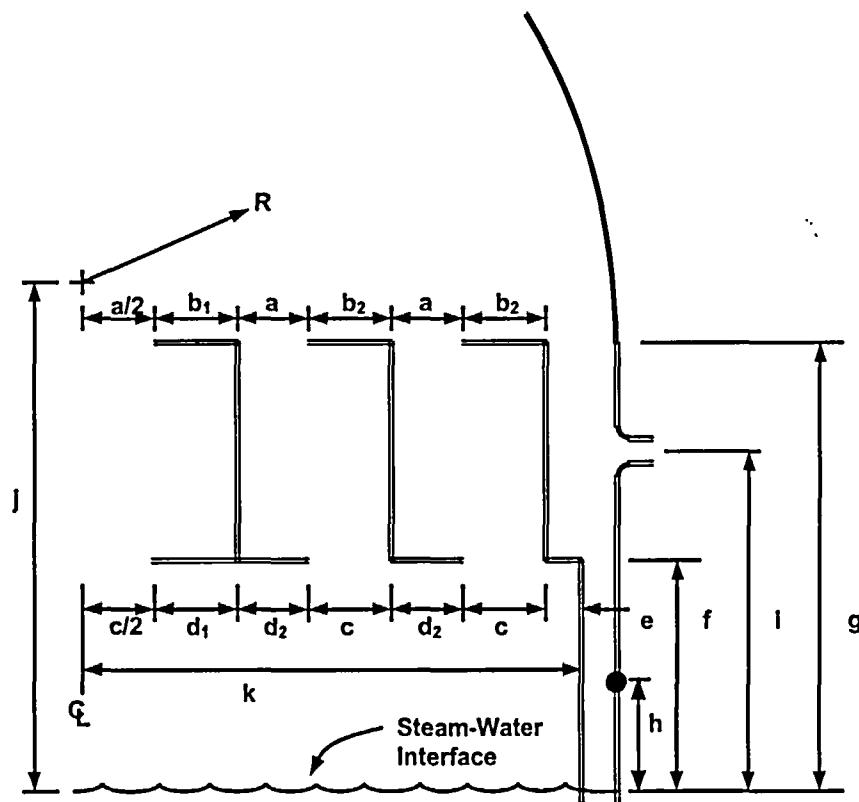




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VY - Acoustic Load Definition (cont.)

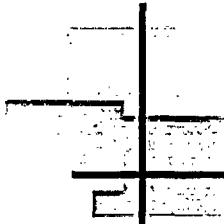
- Acoustic circuit model domain details:



$$\nabla^2 P + \frac{\omega^2}{a^2} P = 0$$

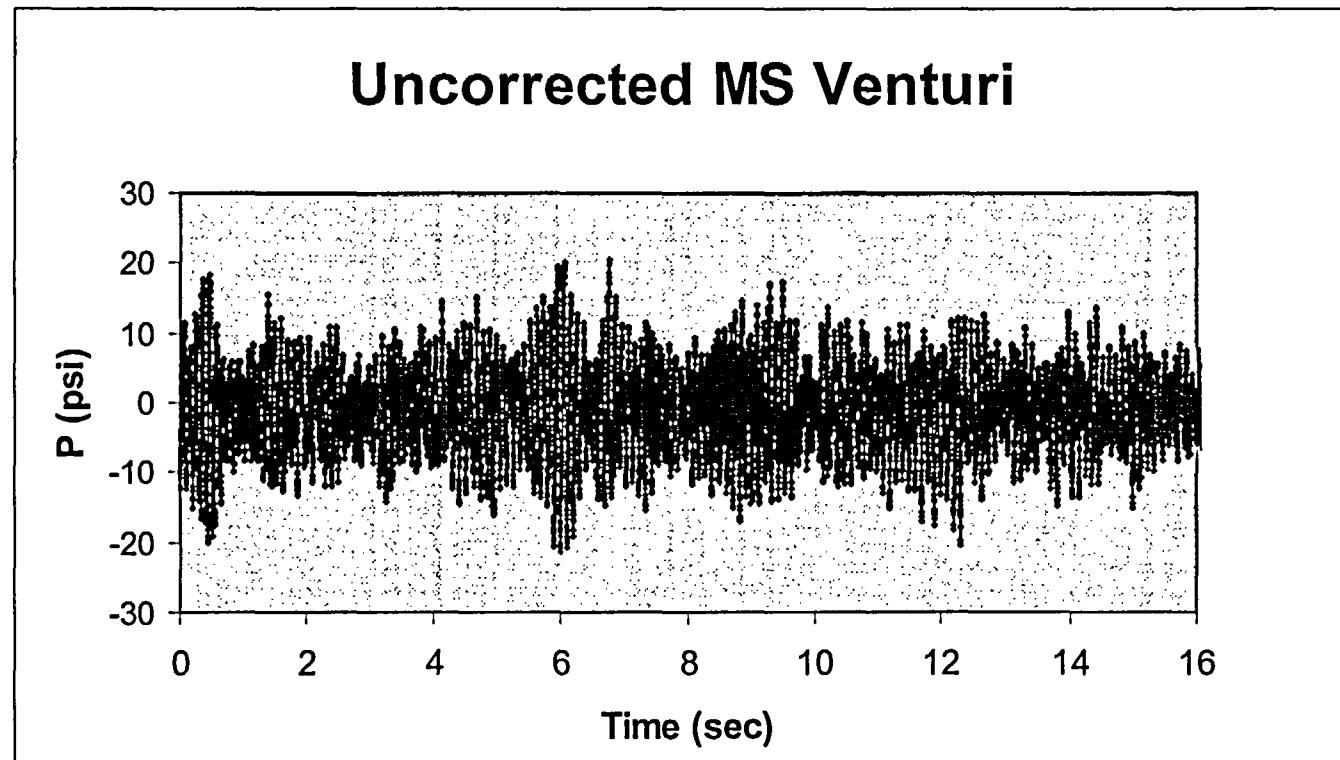


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VY - Acoustic Load Definition (cont.)

- Main Steam Instrument Line Data - Uncorrected:

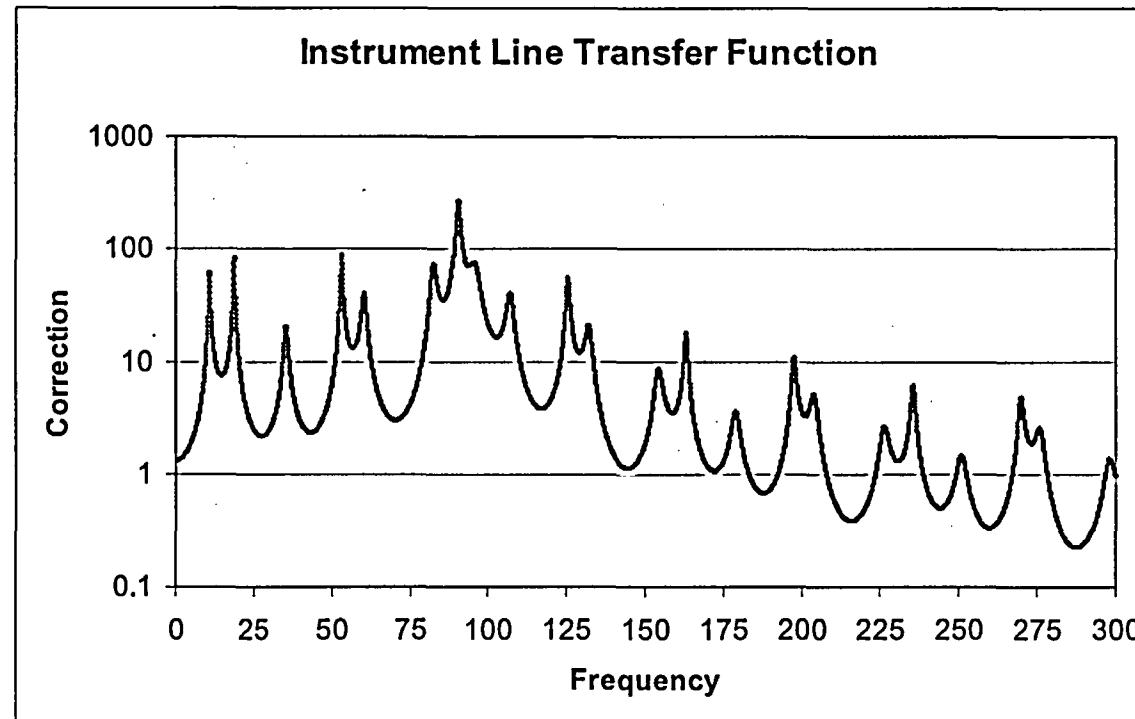




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VY - Acoustic Load Definition (cont.)

- Main Steam Instrument Line Data Correction:

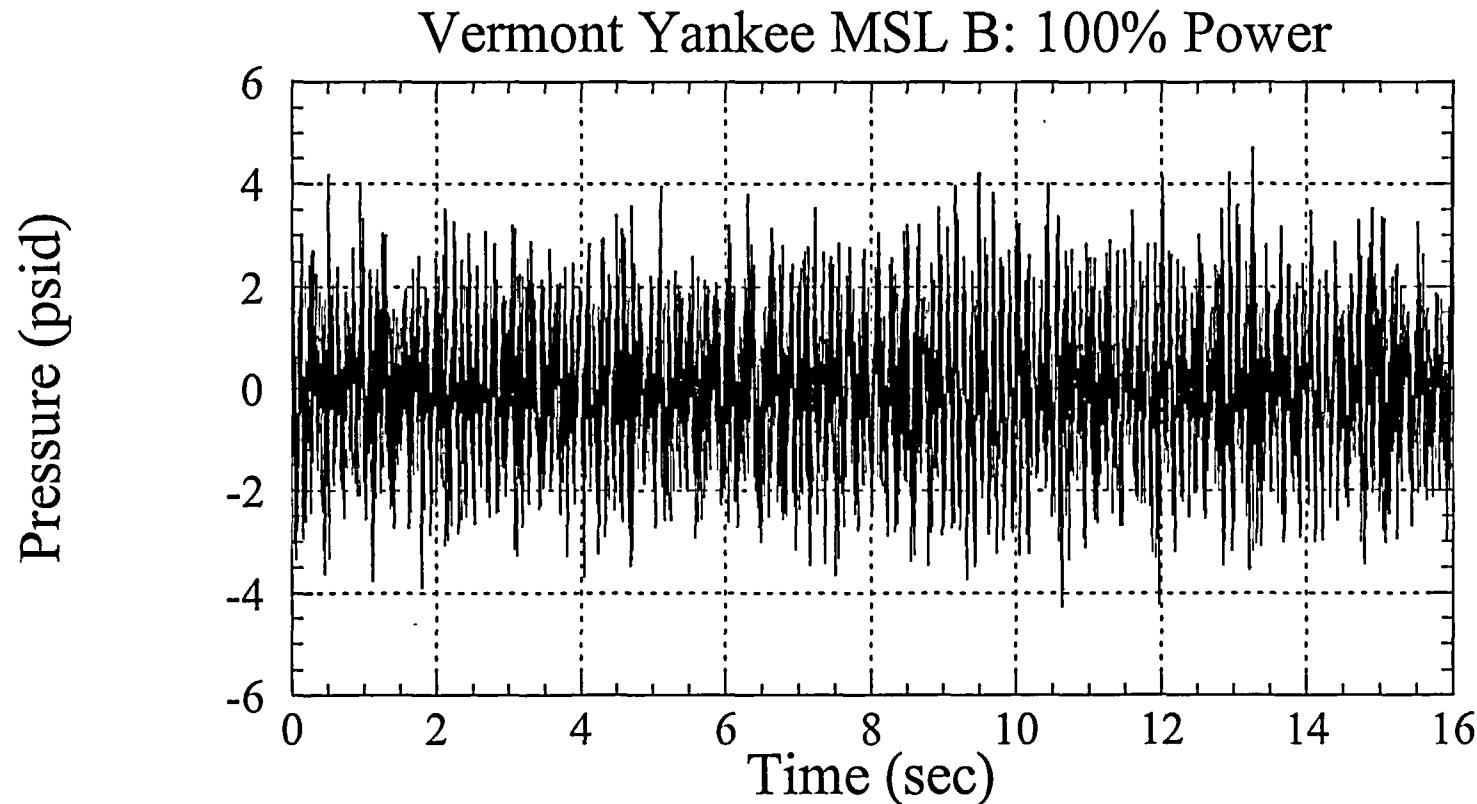




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VY - Acoustic Load Definition (cont.)

- Main Steam Instrument Line Data (corrected):



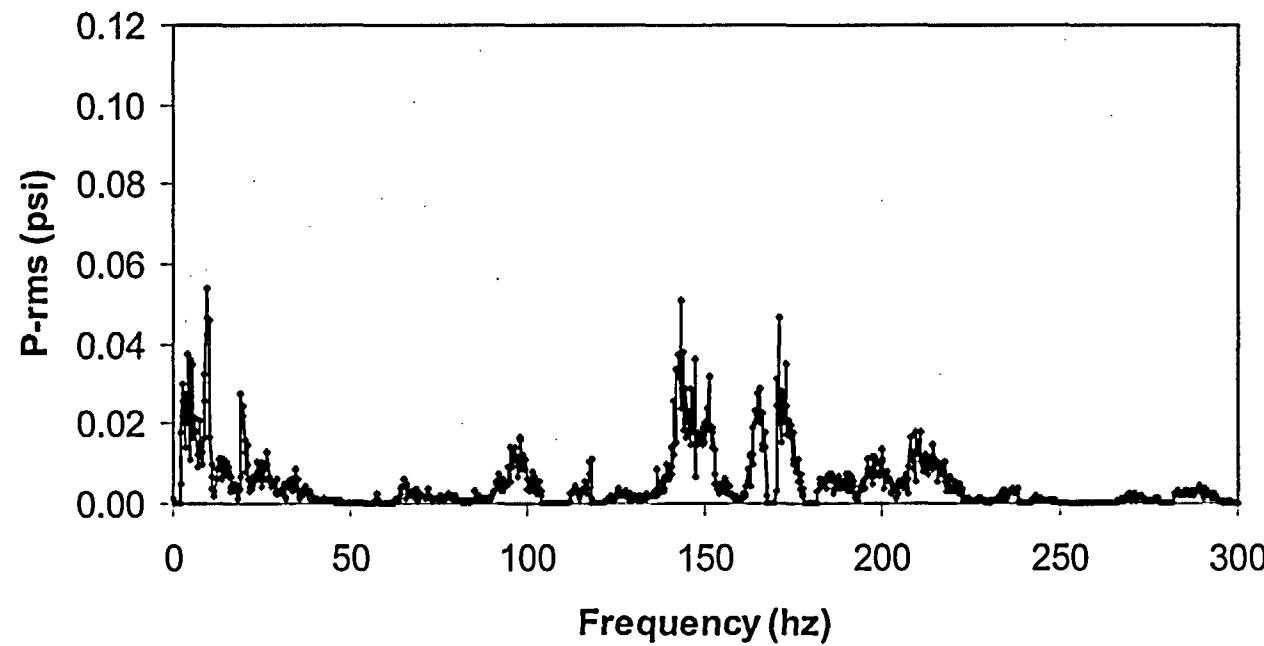


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VY- Acoustic Load Definition (cont.)

- Main Steam P-rms Venturi (corrected)

CLTP 100% Venturi MS "B"

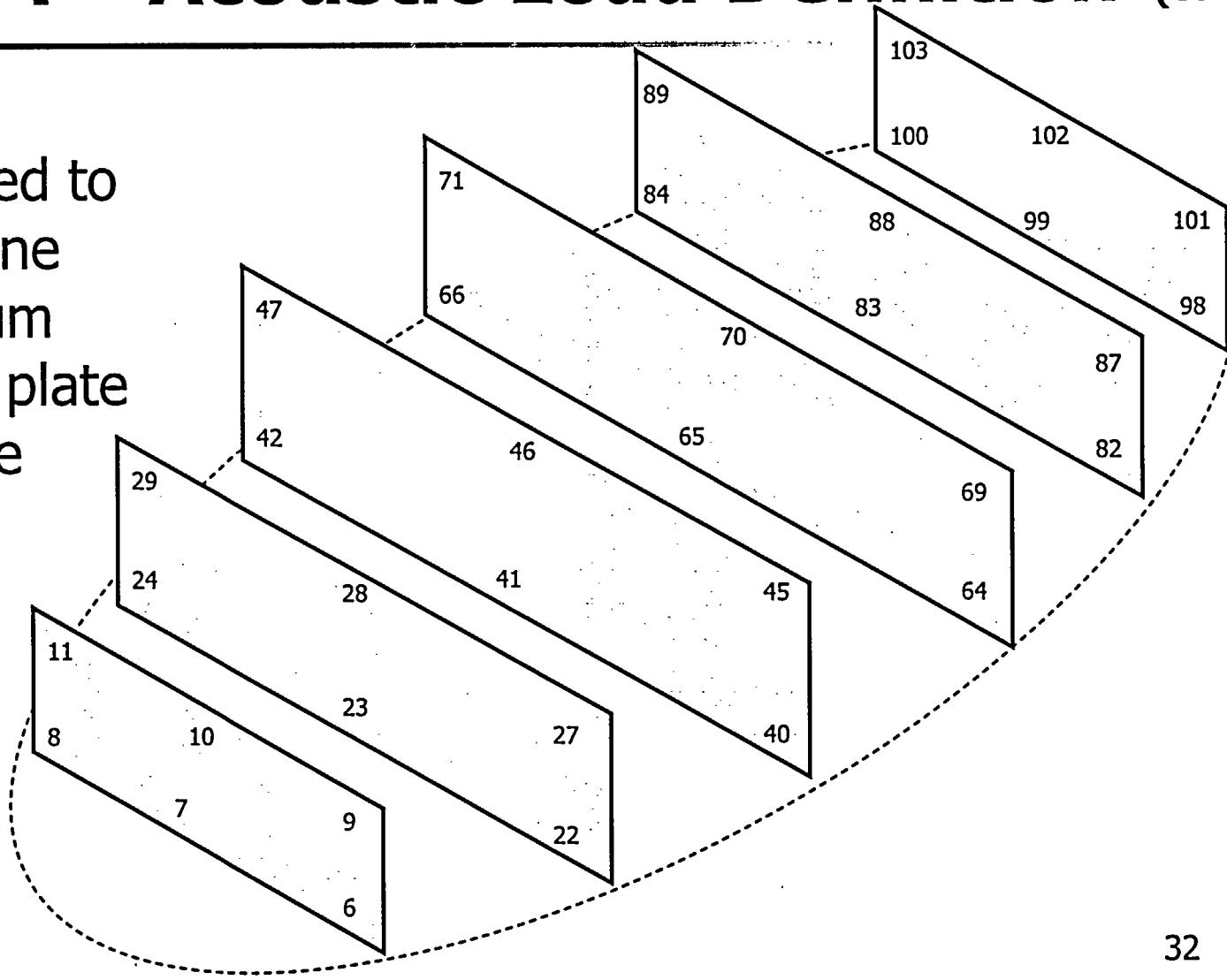




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VY - Acoustic Load Definition (cont.)

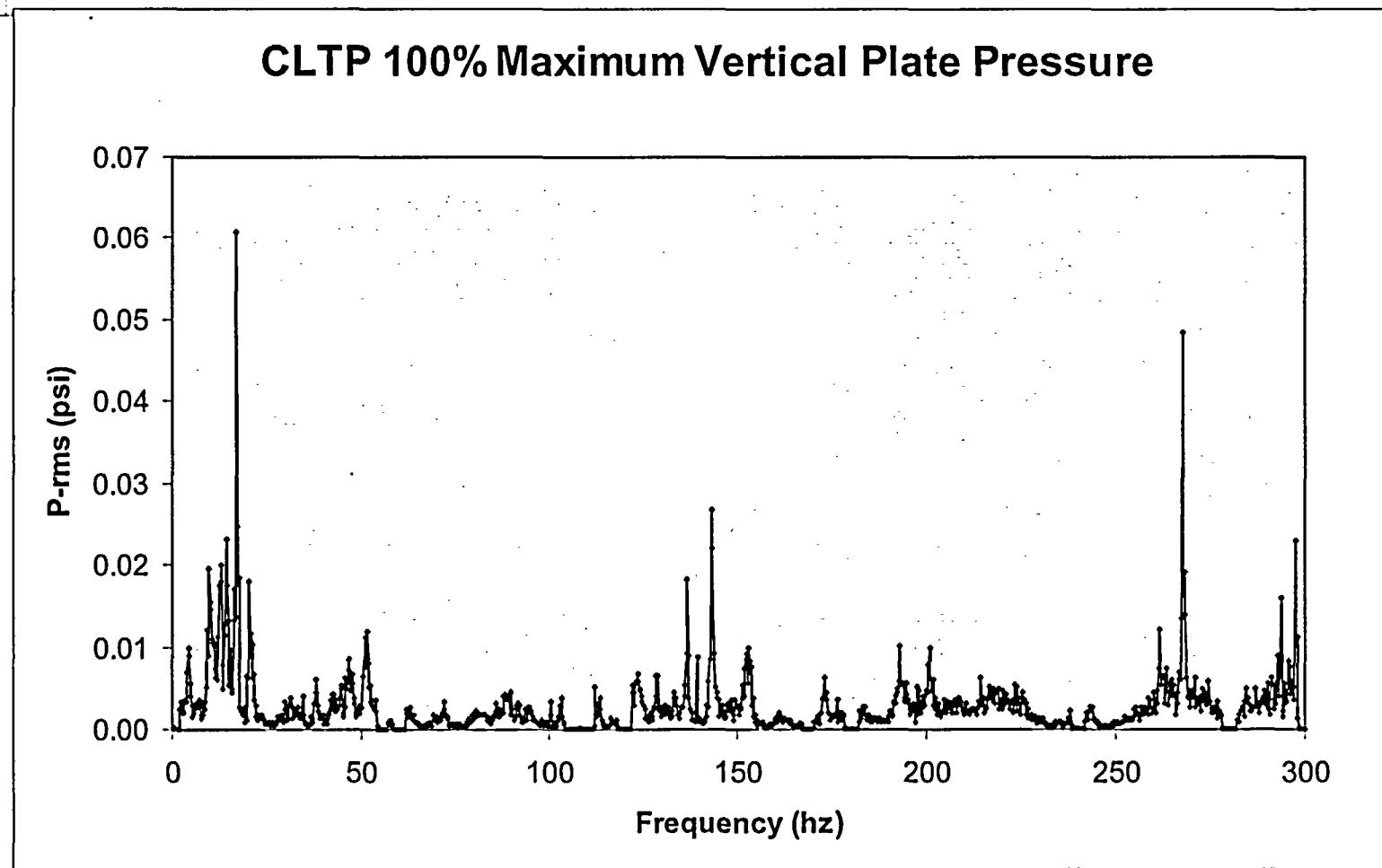
Nodes
evaluated to
determine
maximum
vertical plate
pressure





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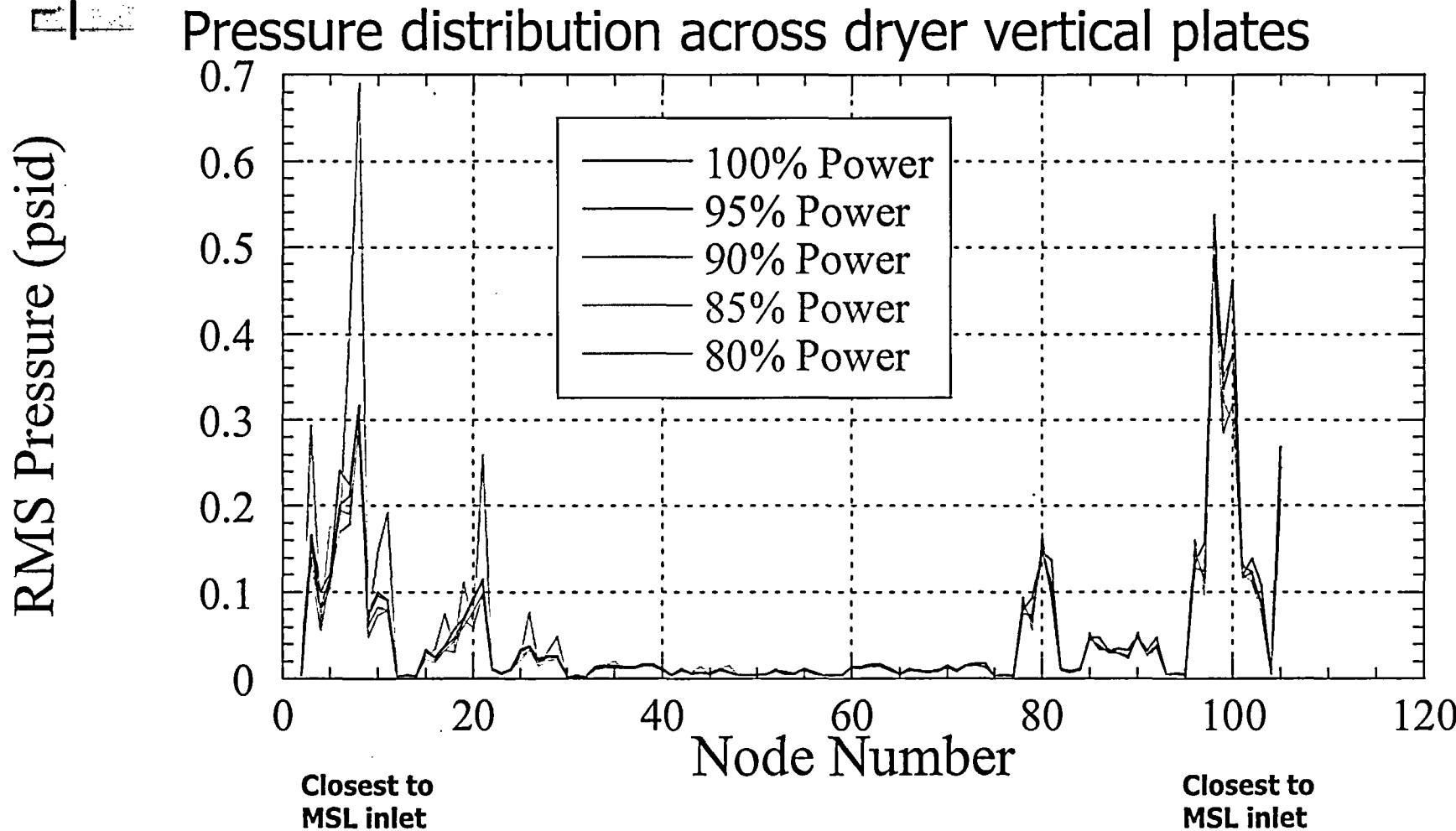
VY – Acoustic Load Definition (cont.)



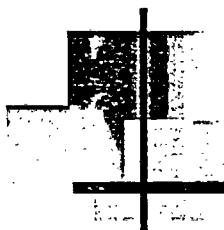


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VY - Acoustic Load Definition (cont.)



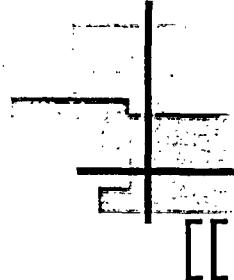
Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes



Prepared by:

Continuum Dynamics, Inc.
Ewing, New Jersey

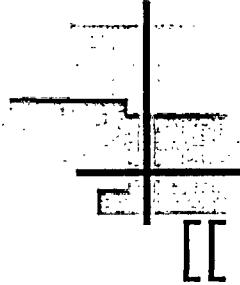
Prepared for:
Entergy Nuclear Northeast
Vermont Yankee
Vernon, VT



Flow Induced Vibration in BWR Plants

General Observations

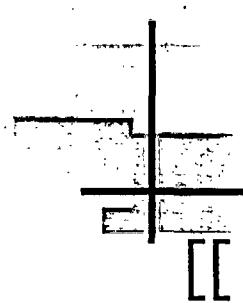
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Flow Induced Vibration in BWR Plants

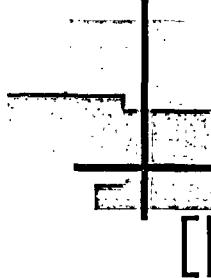
General Observations

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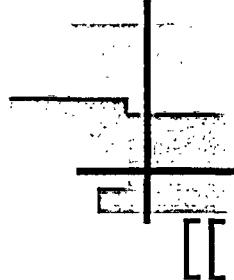
Flow Induced Vibration Issues Scaling and Physical Considerations

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Flow Induced Vibration Issues Scaling and Physical Considerations

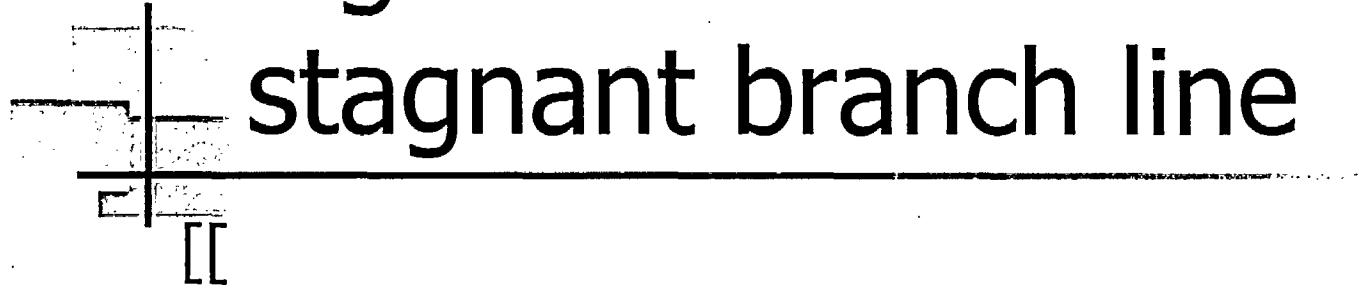
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Vorticity Induced Unsteadiness

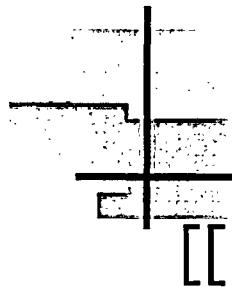
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Figure 2.1 Oscillation in a stagnant branch line

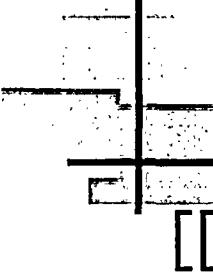


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Figure 3.2 Conceptualization of source regions

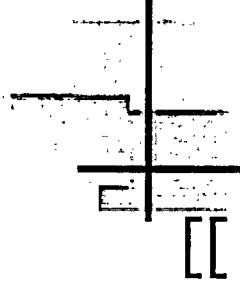


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Junctions in the Steam Line

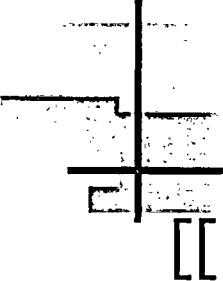
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Loads Transfer Methodology in BWR Plants

Motivation and Approach Overview

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Loads Transfer Methodology in BWR Plants

Motivation and Approach Overview

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Loads Transfer Methodology in BWR Plants

Motivation and Approach Overview

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Component Models (continued)

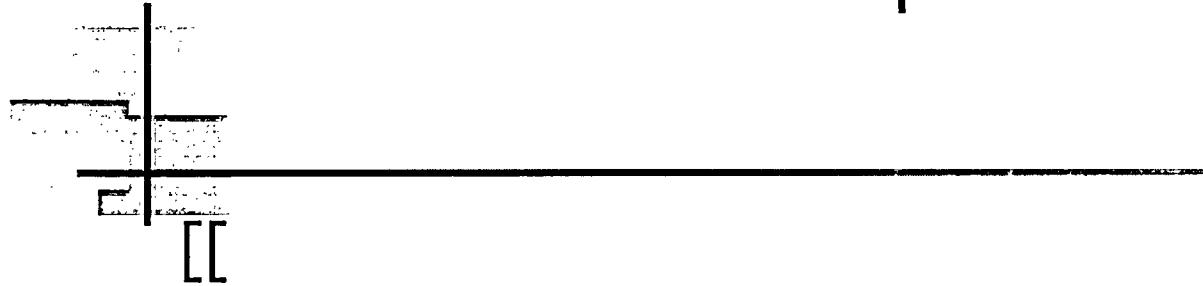
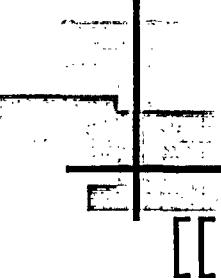


Figure 4.2

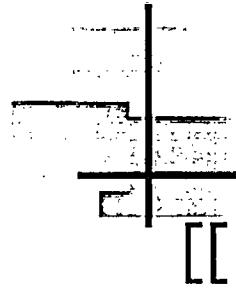
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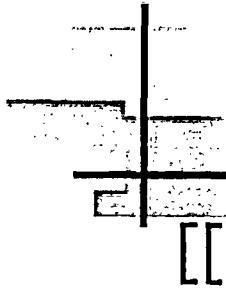
Main Steam Lines

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Steam Dome/Main Steam Line Junction

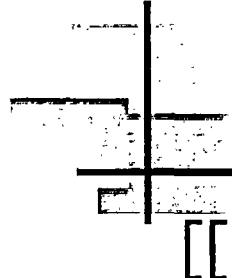


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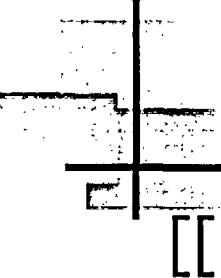
Branch Line Junction

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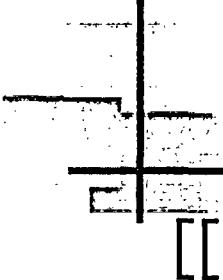
Control Valves

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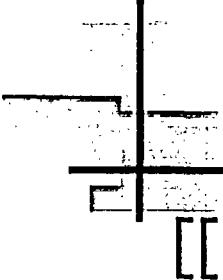
Model Assembly

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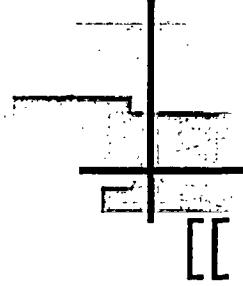
Model Assembly (continued)

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Model Assembly (continued)

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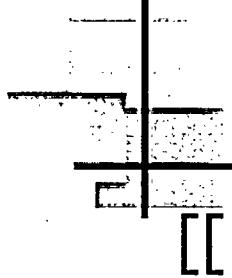


n'_a and n'_b for EPU Load

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Example Information

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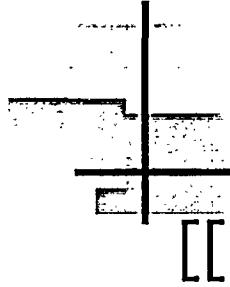
n'_c and n'_d for EPU Load

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Example Information

56

η'_a and η'_b for EPU Load --
PSD



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A Comparison of the data on Figure 6.4 with predictions tabulated below

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Figure 6.4 EPU pressure time history and PSD derived from strain gage data

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Figure 6.6 EPU strain gage pressure and PSD predictions with the current methodology, for an acoustic speed of
[[] ft/sec.

[[

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Figure 6.5 EPU strain gage pressure and PSD predictions with the current methodology, for an acoustic speed of [[]] ft/sec.

[[

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VY Dryer Node Diagram

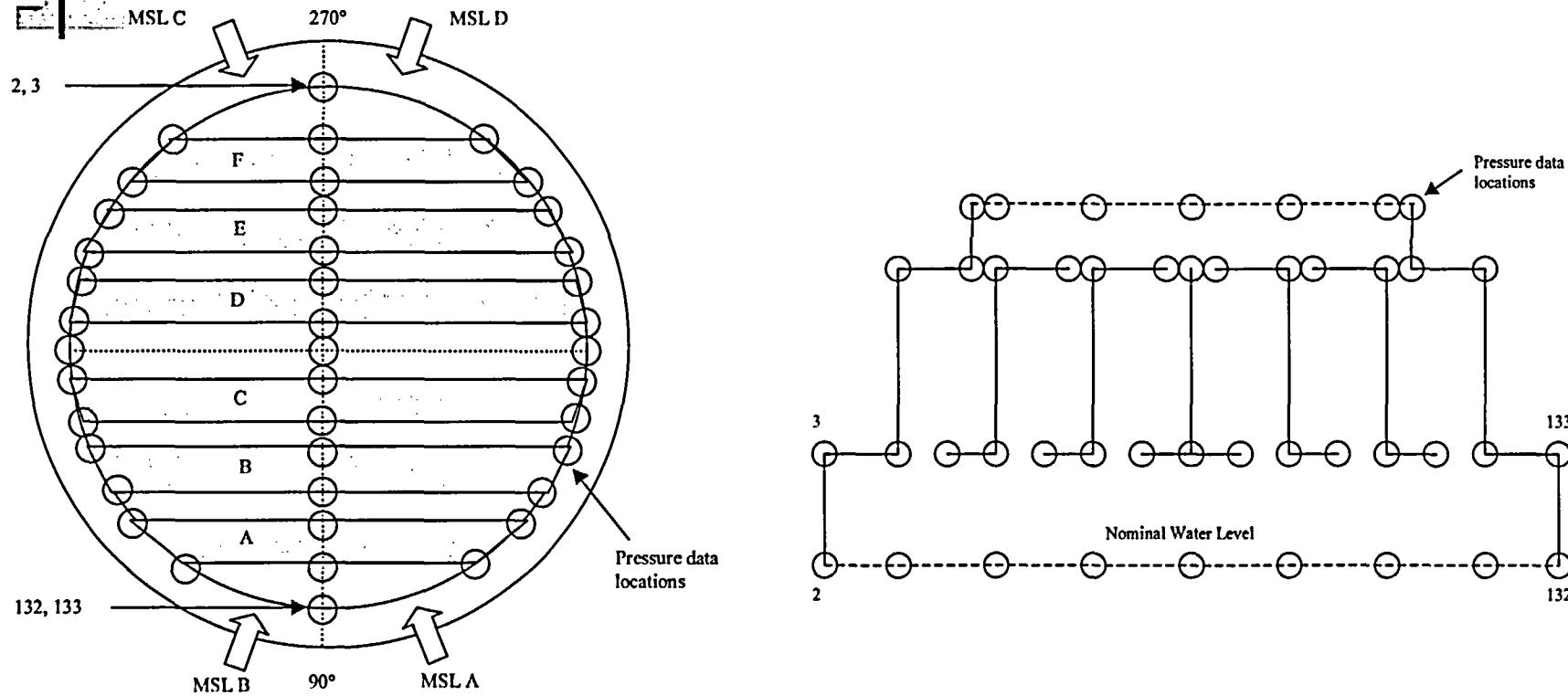
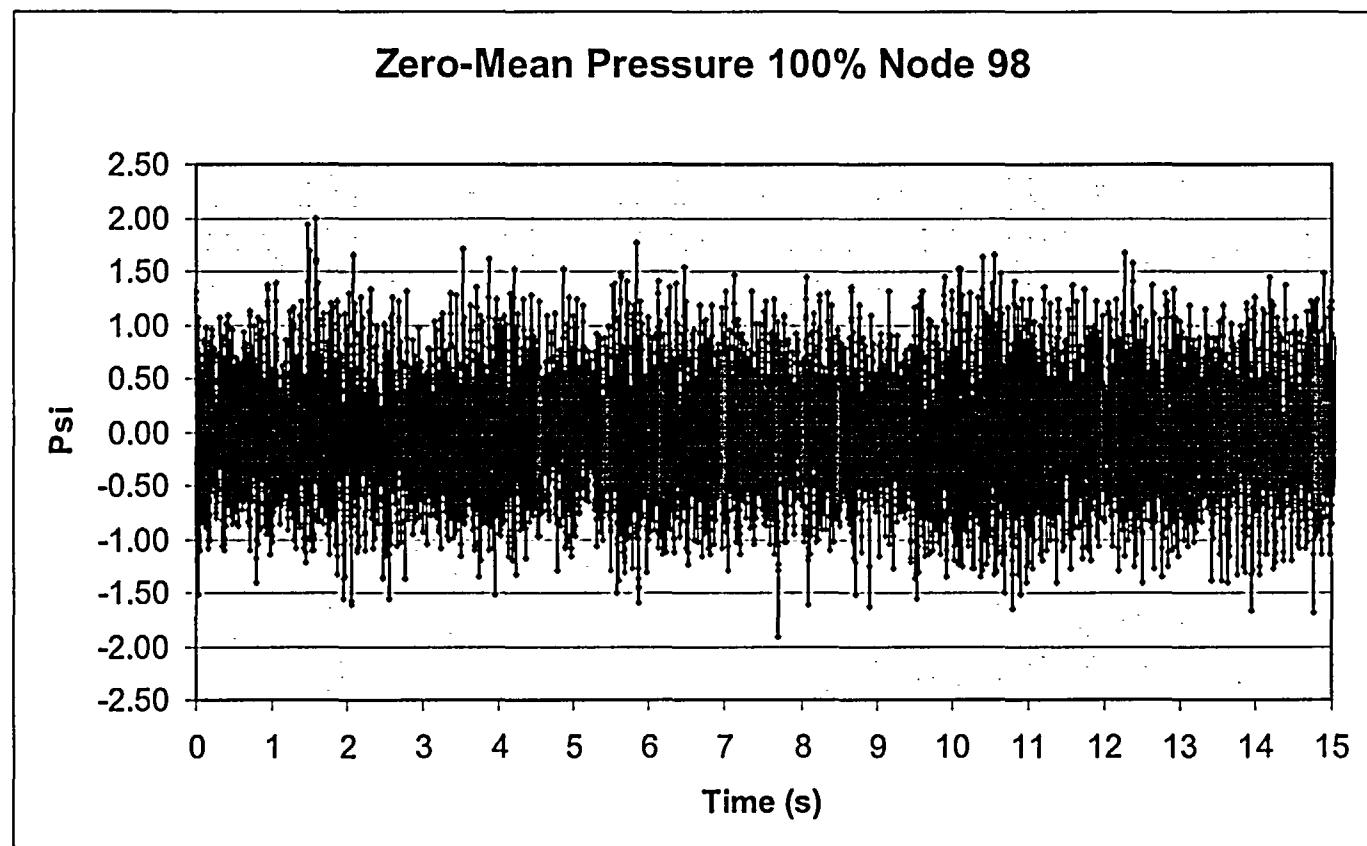
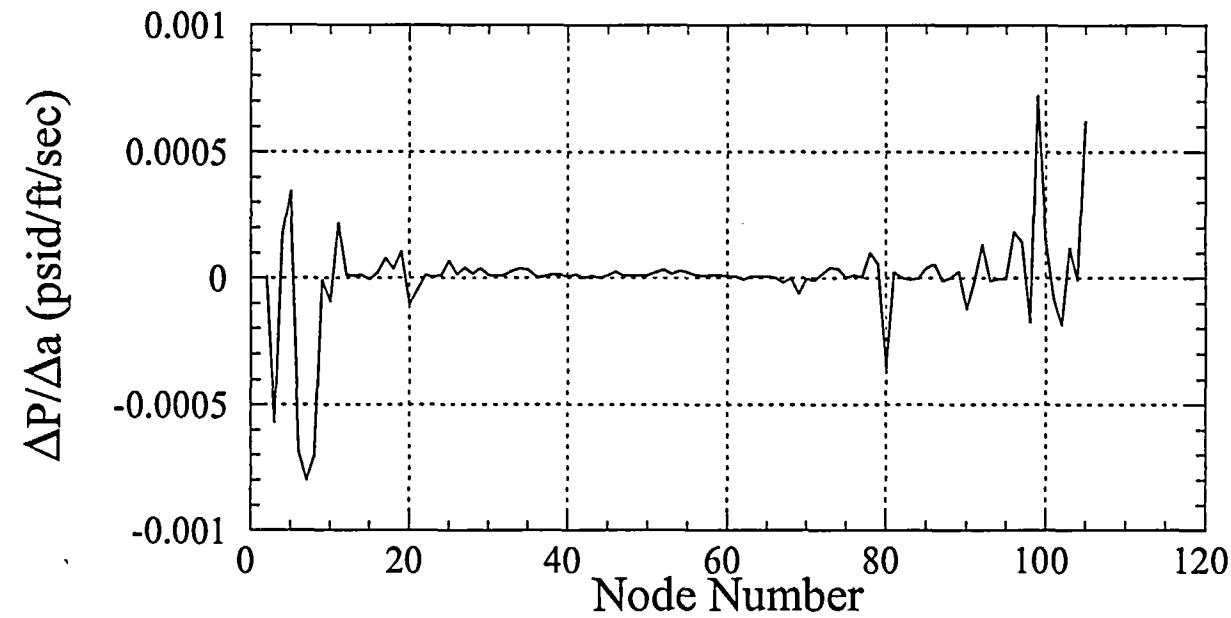


Figure -A.1 Top and side view schematic of pressure node locations on the steam dryer.

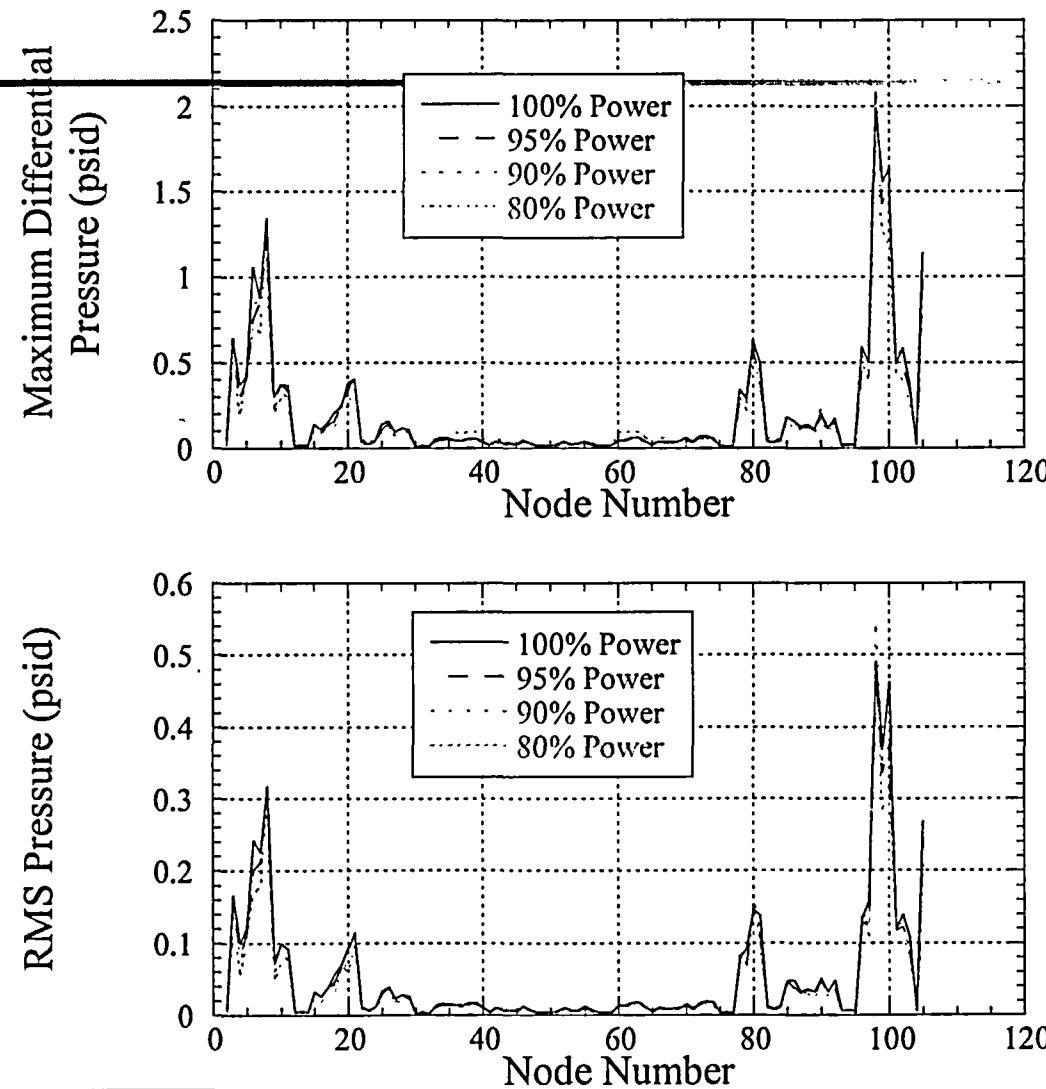
Pressure Time History – Dryer Face



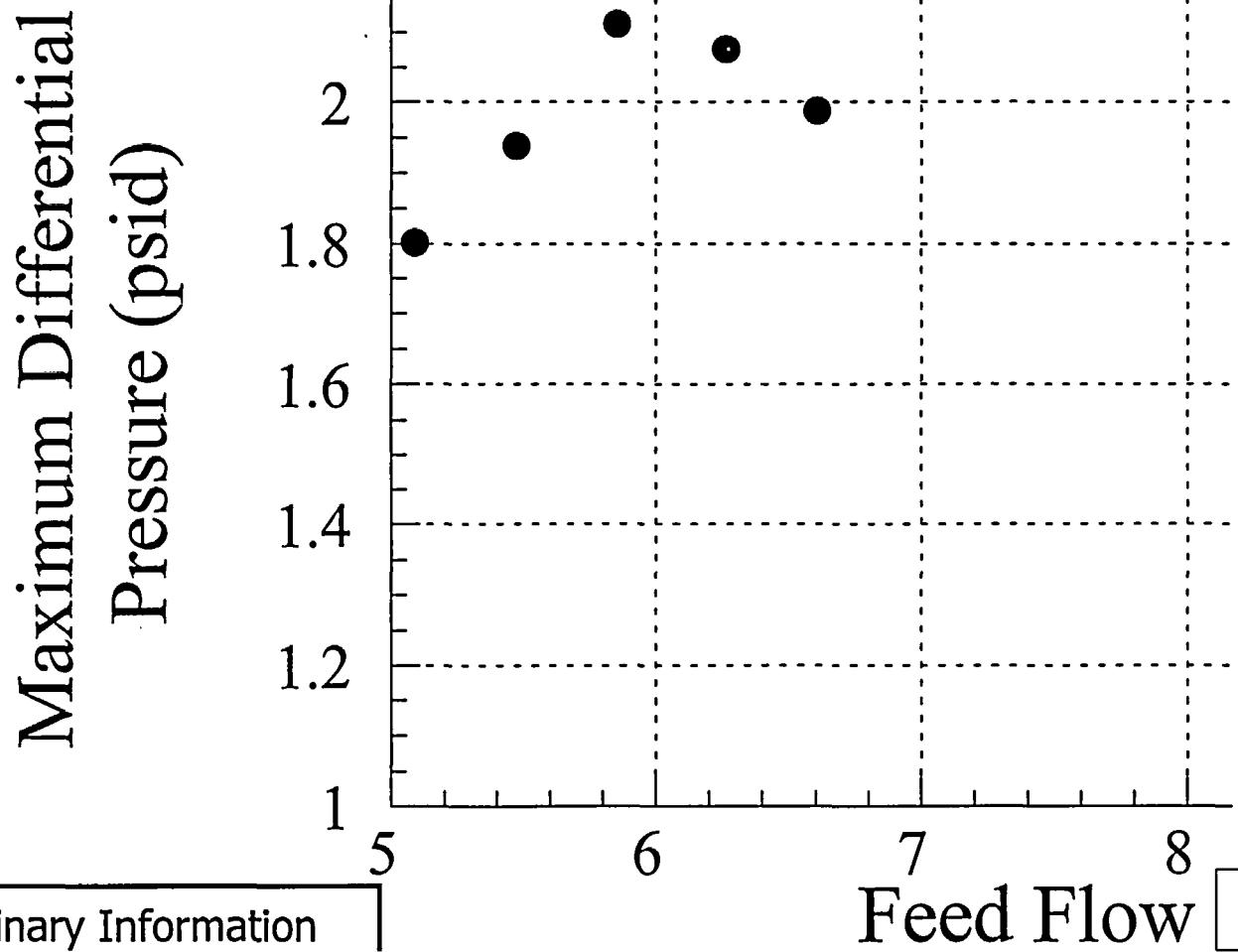
Peak Load Sensitivity



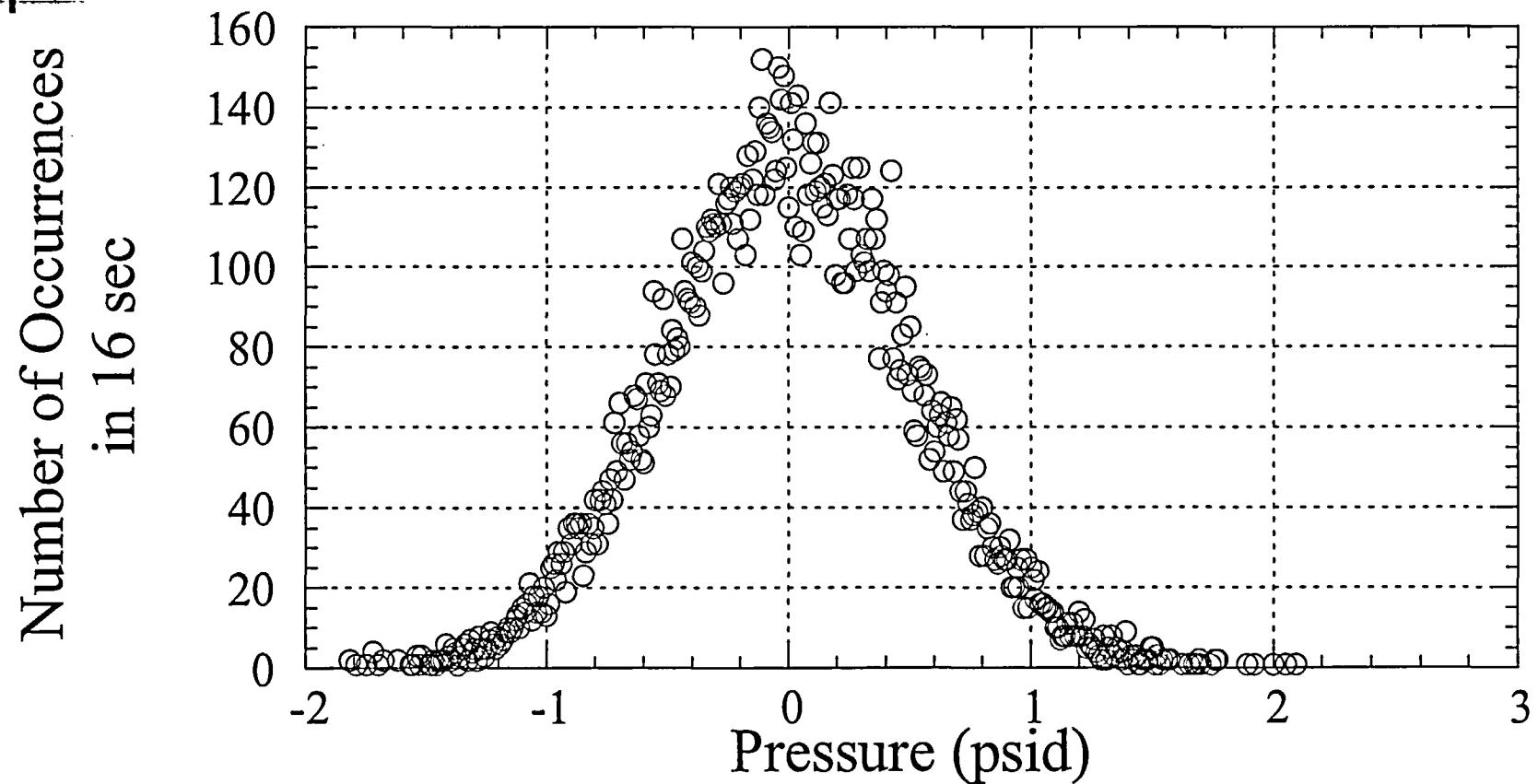
Nodal Predictions



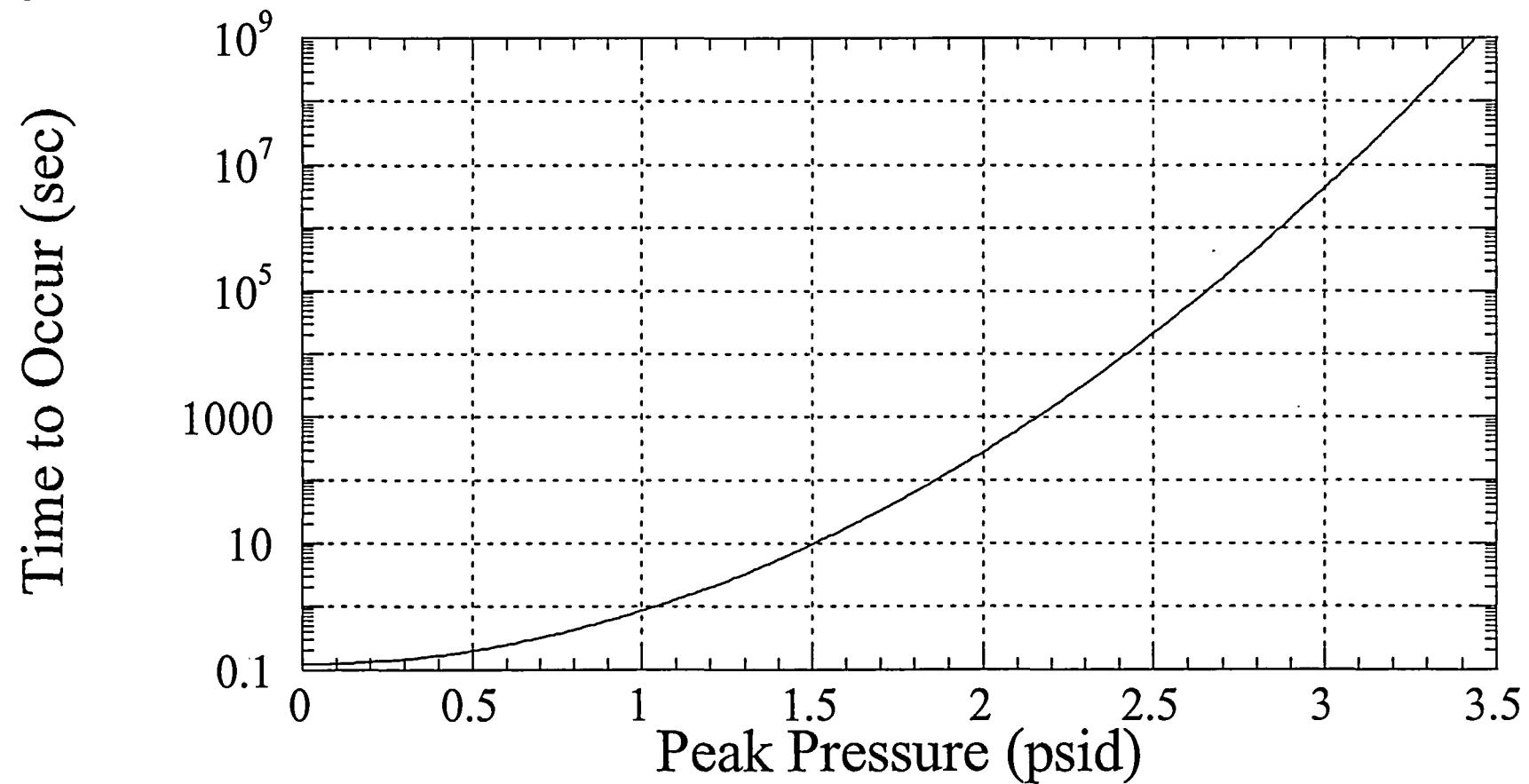
Max Pressure vs Power

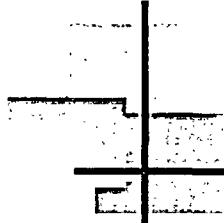


Load Exceedance – Node 98



Time to Exceed – Node 98





VY - Acoustic Load Analysis (cont.)

- Acoustic analysis conclusion:

- VY main steam system has acoustic sources
- Correlation between analytical expectations for physical plant and measured results
- Measured results do not show high amplitude fluctuating pressure loads at CLTP

- Acoustic analysis results application:

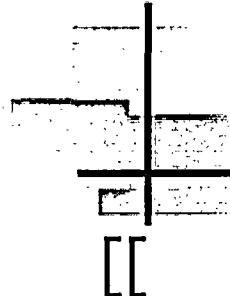
- Analysis results used to create VY plant-specific load definition

Dryer Structural Analysis

- GE application of VY load definition to response spectrum
(same as analysis of record)
- GE application of RS to finite element analysis (ANSYS)
(same as analysis of record)
- GE structural analysis calculates component stresses
(same as analysis of record)



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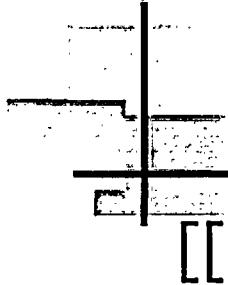


VY – Response Spectrum

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Dryer Structural Analysis (cont.)

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VY - Vortex Shedding Evaluation

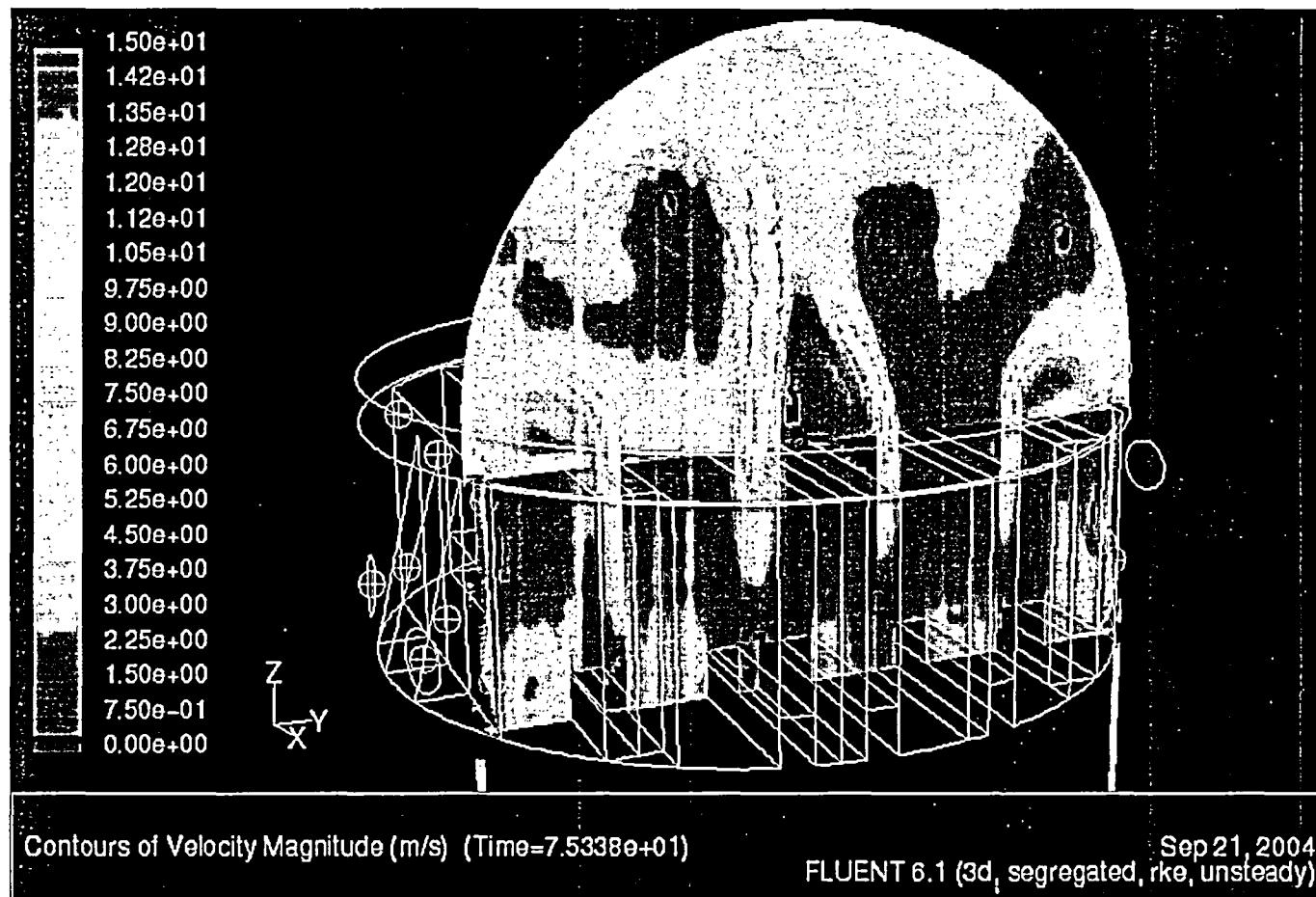
- Purpose: Evaluate vortex shedding
- Fluent - Analytical computational fluid dynamics (CFD) model



Entergy

Unsteady Reynolds Averaged Navier Stokes (URANS) Simulation

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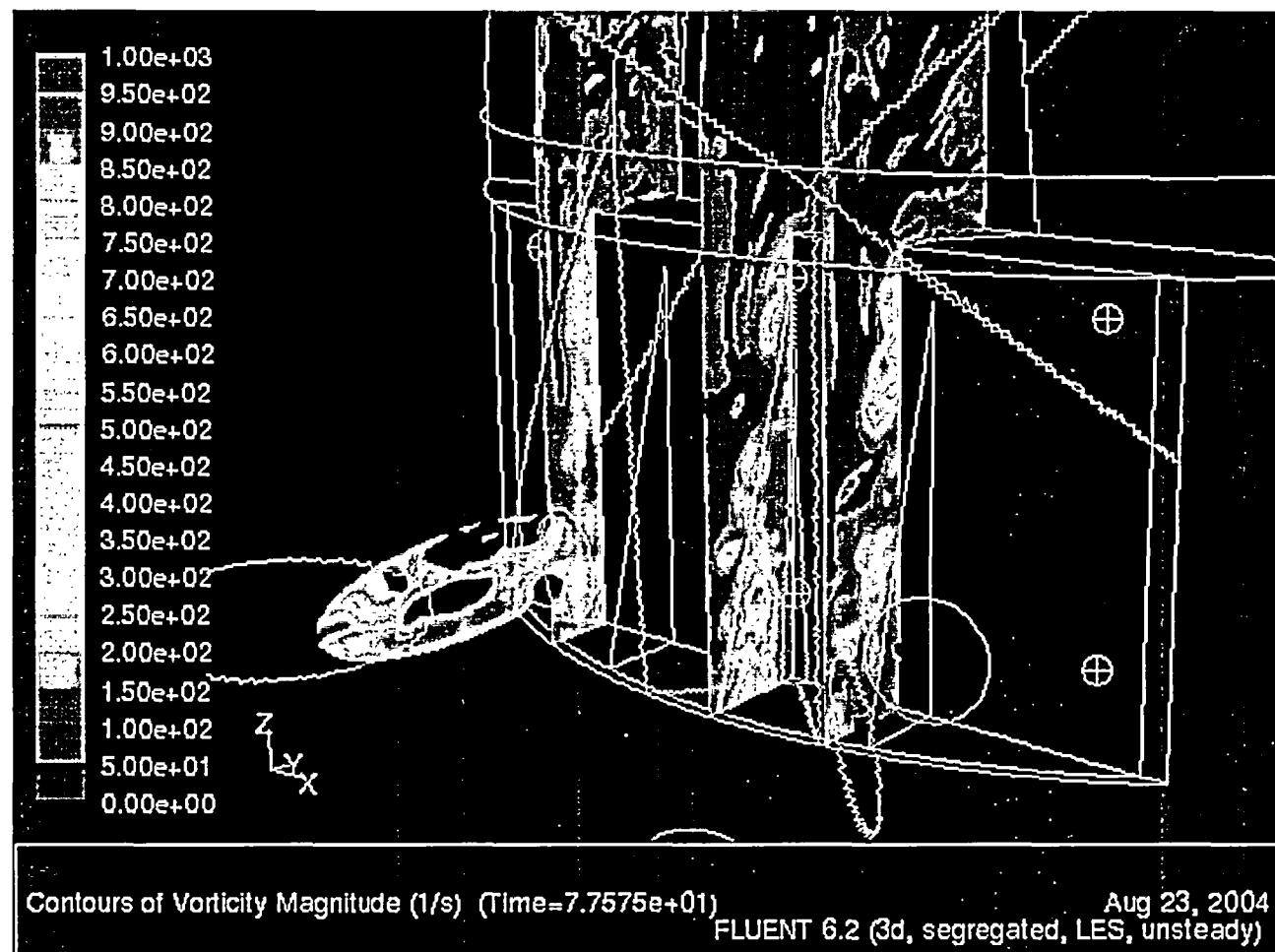




Entergy

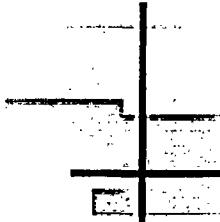
Large Eddy Simulation (LES)

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VY - Vortex Shedding Analysis (cont.)

- CFD model development
- CFD solutions
 - Unsteady Reynolds Average Navier Stokes (URANS)
 - Large Eddy Simulation (LES)



VY - Vortex Shedding Analysis (cont.)

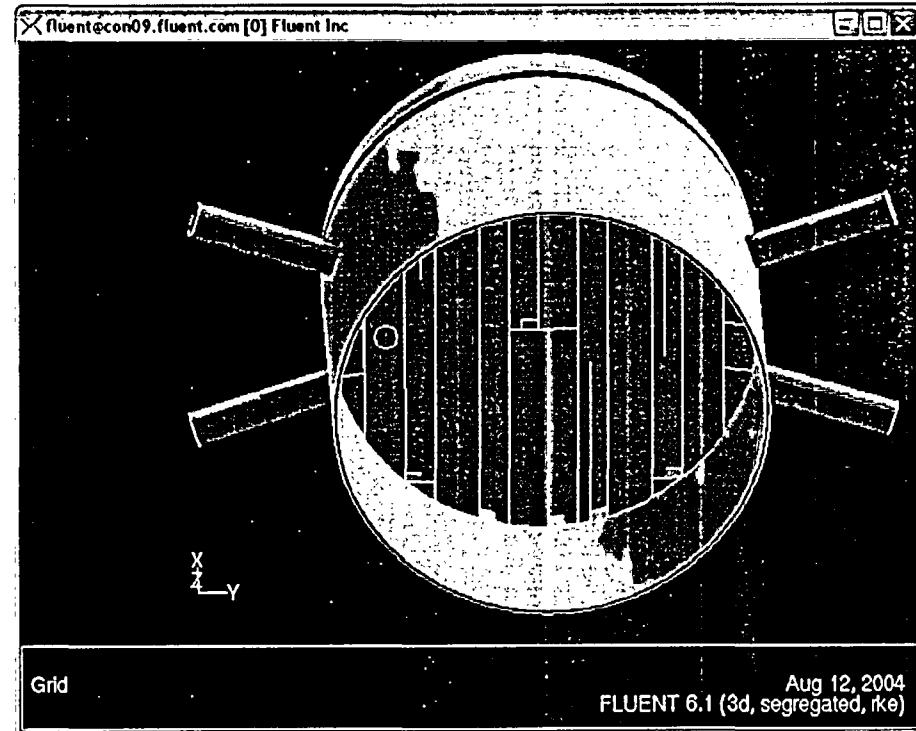
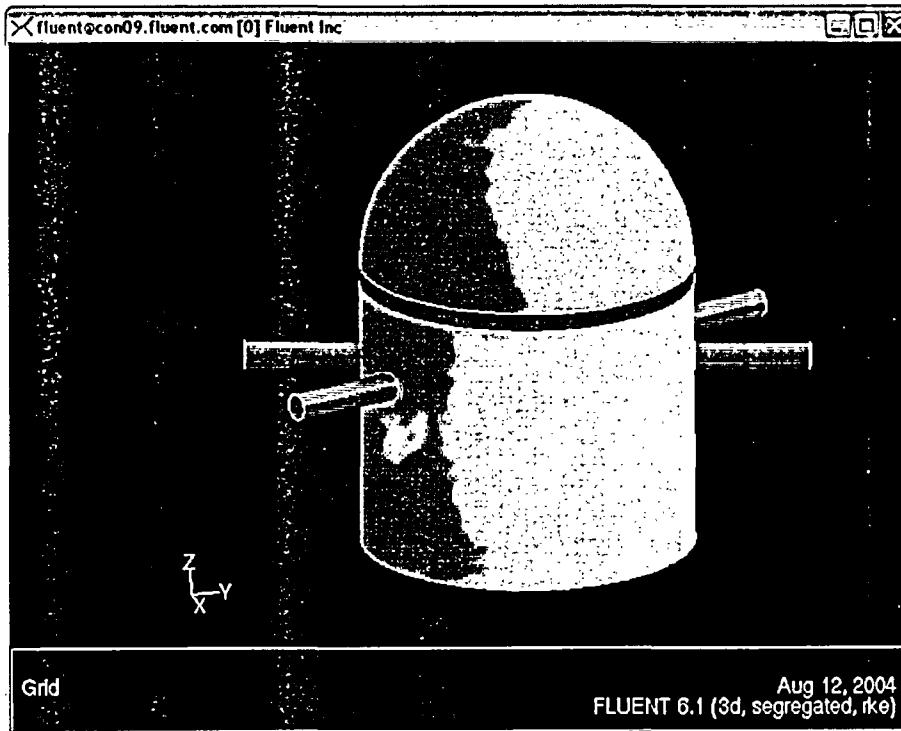
- CFD model development:
 - Methodology - Fluent
 - Boundaries, geometry & mesh
 - ◆ URANS domain: RPV Dome, RPV annular region, Dryer internals and Skirt
 - ◆ LES: limited domain
 - URANS unsteady solution provides LES boundary conditions
 - LES solution capable of modeling local vortices at cover plate



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VY – CFD Model

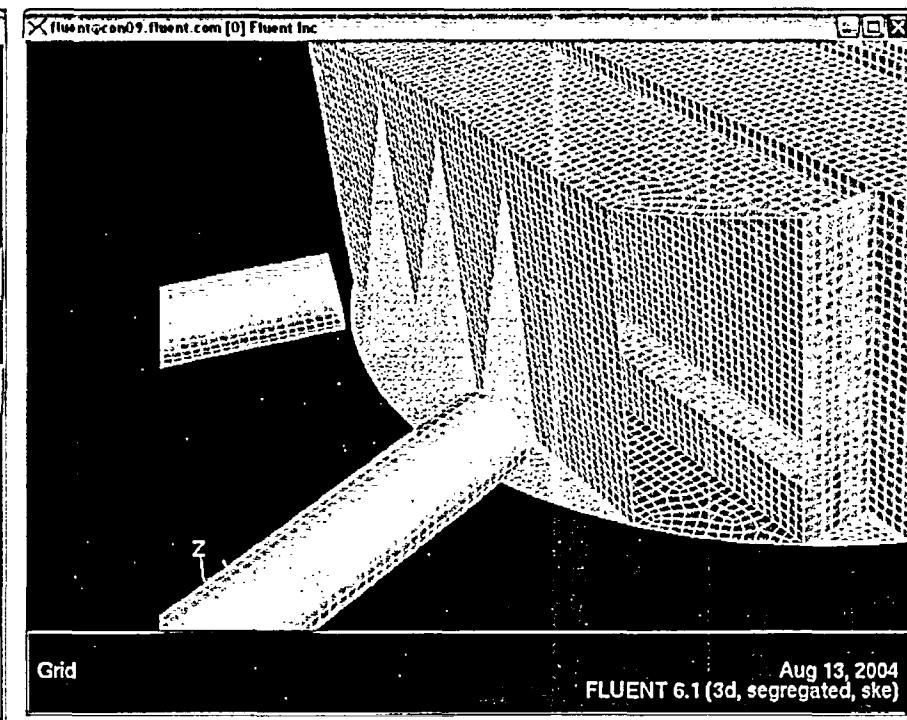
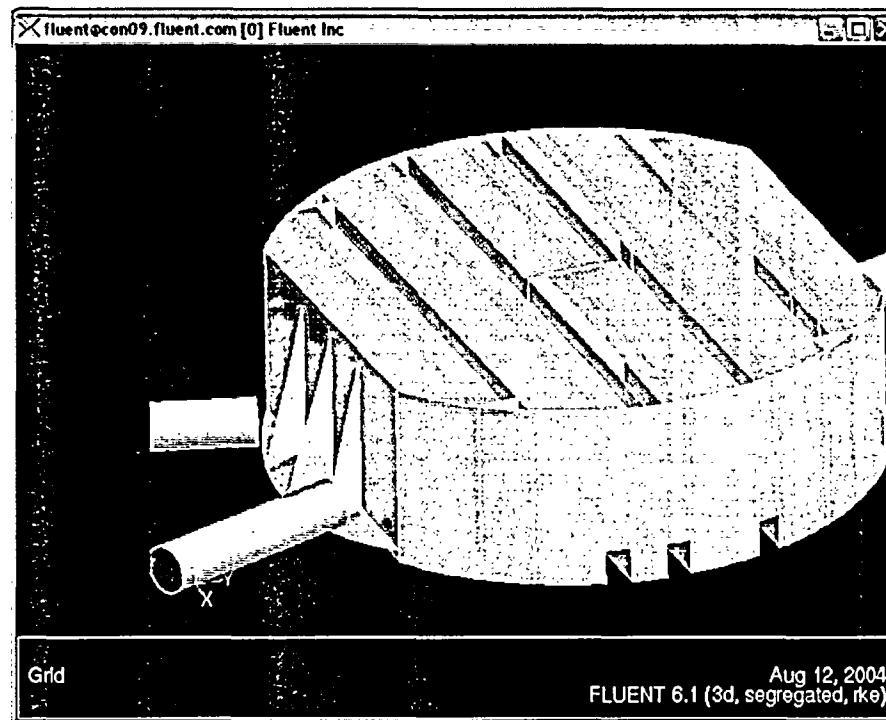
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VY – CFD Model (cont.)

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URANS Evaluation

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- URANS evaluation performed to establish:
 - Basic understanding of flow field
 - Characterizing turbulence field for estimating LES model cell size
 - Define inlet boundary conditions for LES model

URANS Evaluation (cont.)

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■ URANS model

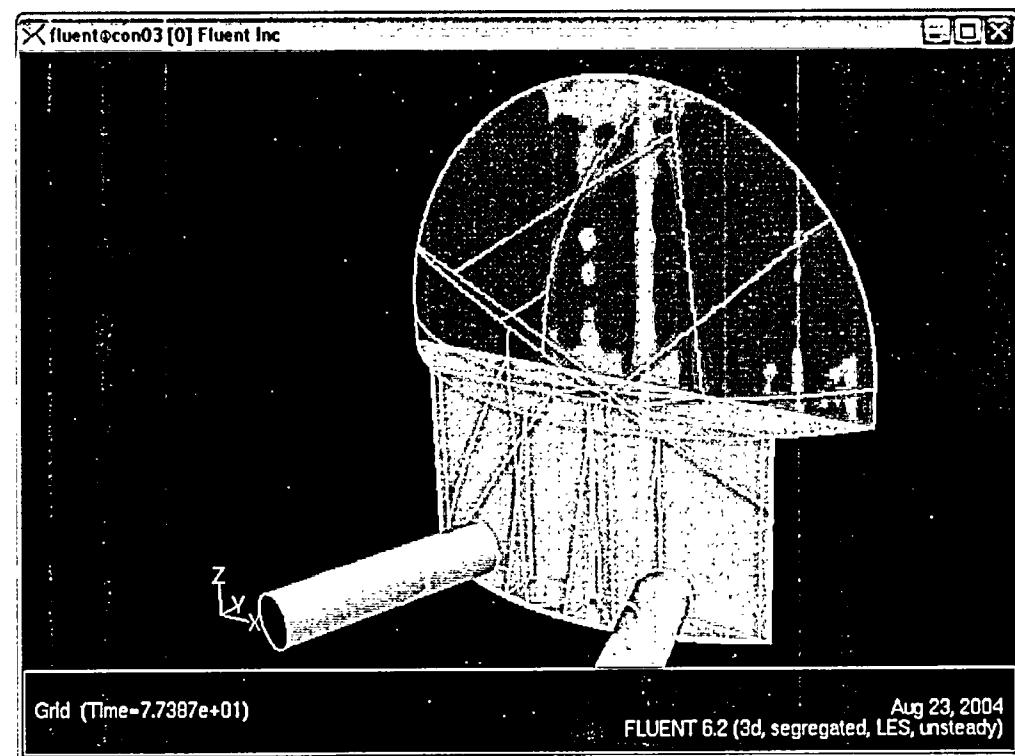
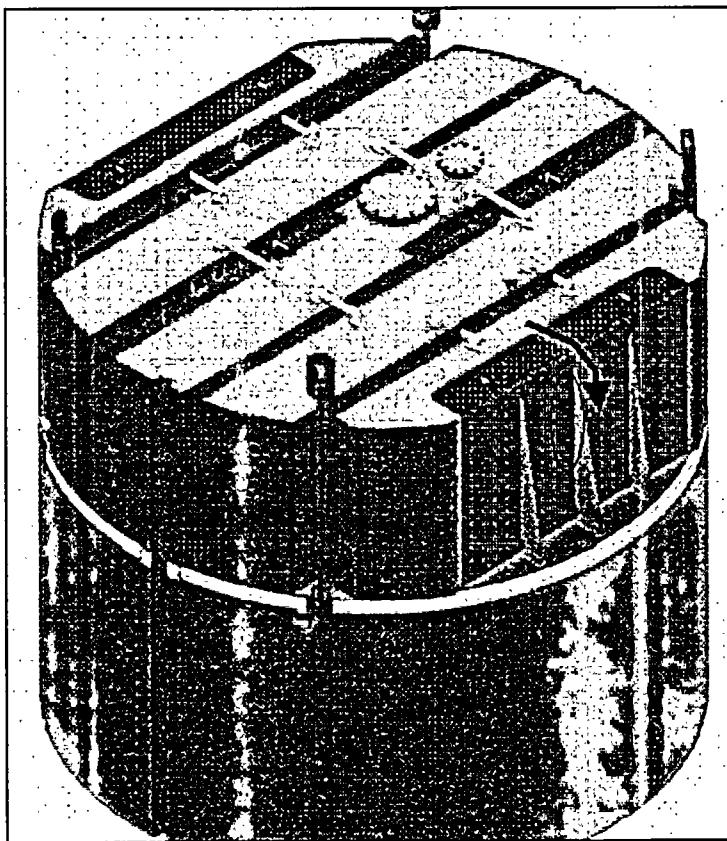
- 875K cells, hybrid mesh
- Incompressible, isothermal, unsteady



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LES Evaluation

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LES Evaluation (cont.)

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- Boundary conditions same as RANS model, when applicable.
- 2 Million mesh
- Time invariant profile of u , v , w , k , e from RANS solution imposed at velocity inlet



VY Vortex Shedding Evaluation (cont.)

- CFD evaluation status:

- Vortex shedding is contributor to dryer loads at low frequencies
- Contribution is visible in plant data
- Conclusion will be validated

VY - Load Definition

- VY dryer 120% EPU load definition:
 - MS acoustic loads at 120% EPU power conditions
 - ◆ GE applied MS velocity scaling (RAI EMEB-B-8 response) to EPU condition



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VY FIV Comparison

- VY FIV measurements comparisons:
 - Benchmarking VY measured data against other plants
 - MSL piping measured vibration comparisons

VY FIV Comparison (cont.)

■ Strain gauge measurements:

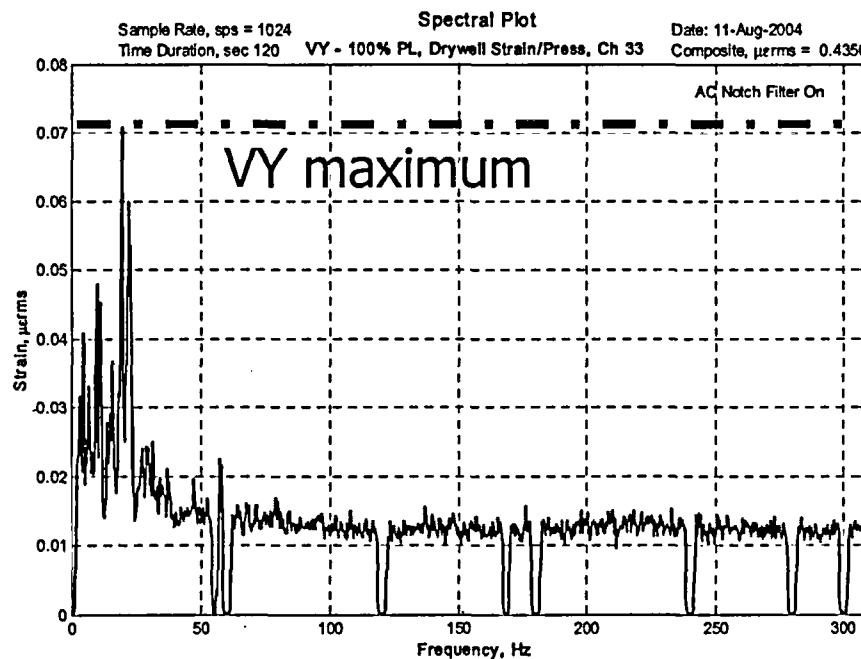
- VY vs. QC2 100% OLTP strain gauge measurements
 - ◆ Similar noise floor $\sim 0.014\mu\text{e}$
 - ◆ QC has significant strain peaks at 137 Hz and 160 Hz that are not present at VY



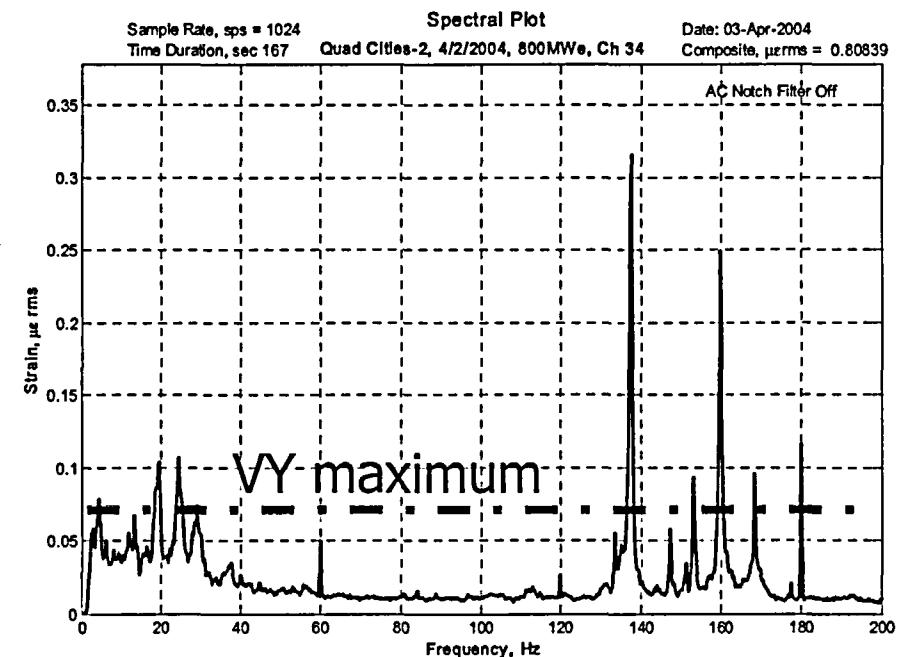
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VY FIV Comparison (cont.)

VY vs. QC2 100% OLTP Strain Measurements



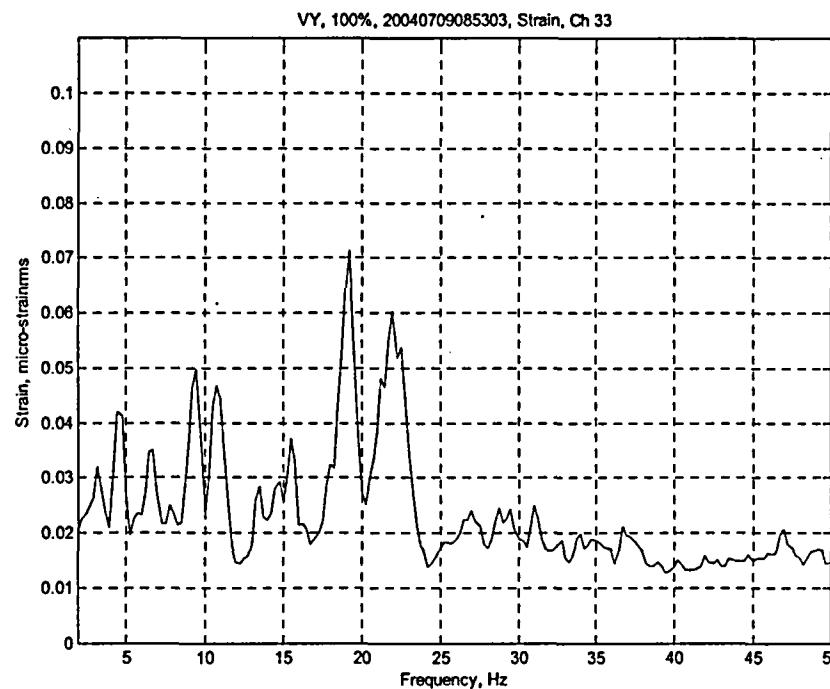
Vermont Yankee



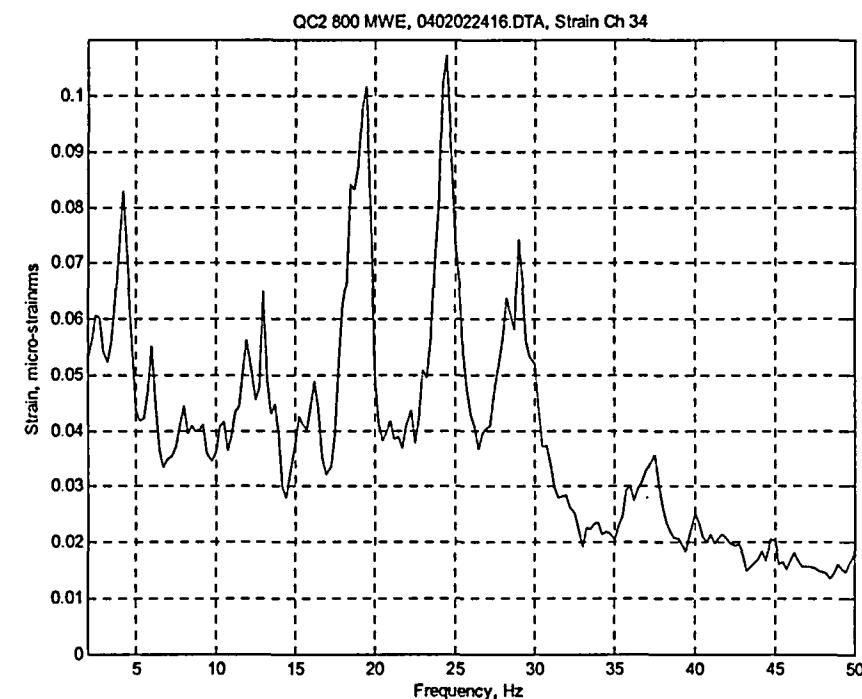
Quad Cities Unit 2

VY FIV Comparison (cont.)

VY vs. QC2 100% OLTP Strain Measurements 0-50 Hz



Vermont Yankee



Quad Cities Unit 2

VY FIV Comparison (cont.)

■ MS Piping Vibration Measurements

- Indicator of acoustic load frequency and amplitude
- Plant EPU vibration comparisons
- Measurements performed 3 times

VY FIV Comparison (cont.)

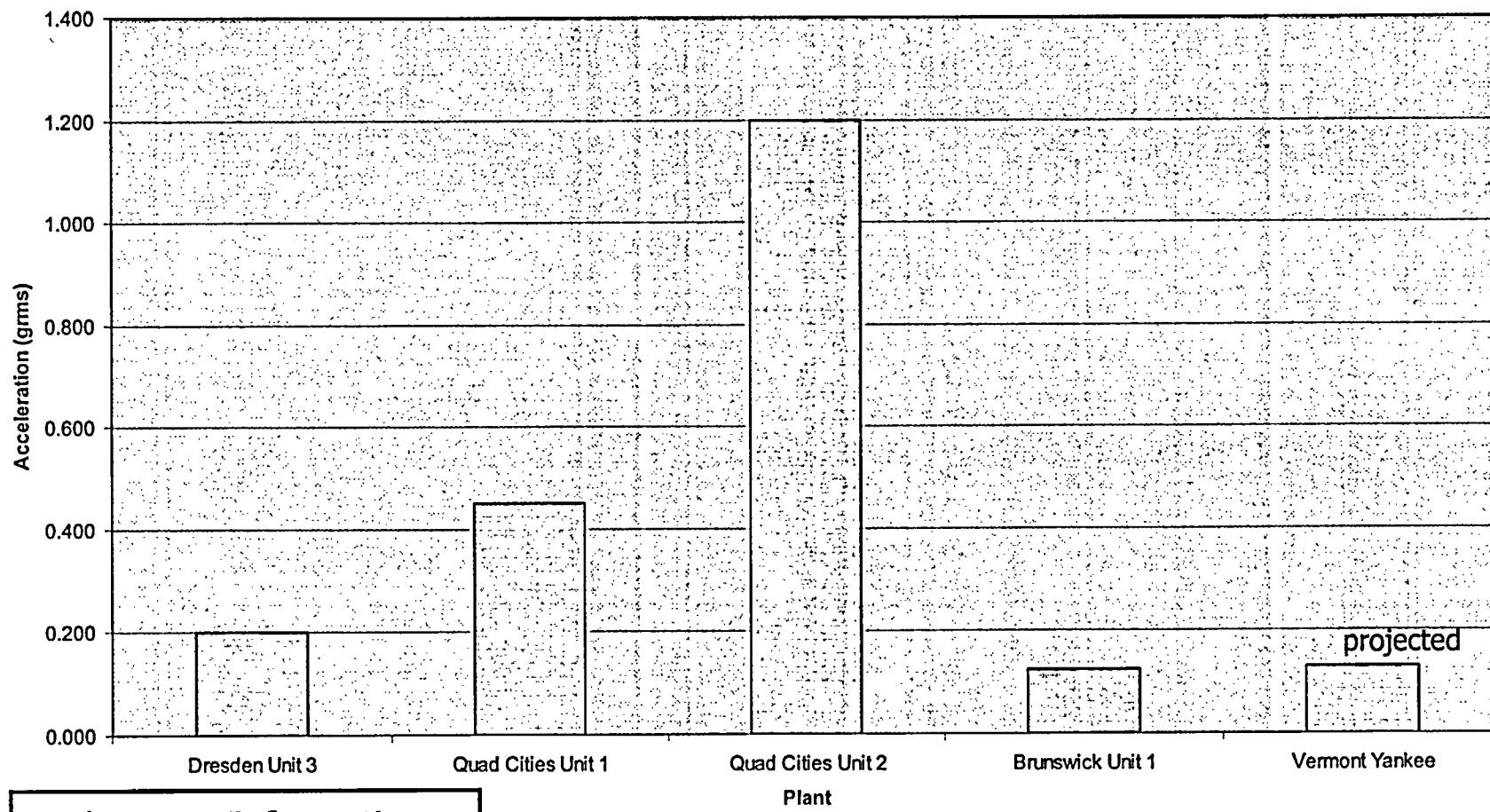
- MS piping vibration plant data
 - Indicator of acoustic load frequency and amplitude
 - Plant EPU vibration comparisons (see chart):
 - ◆ VY CLTP data extrapolated to EPU
 - ◆ Piping vibration similar to Brunswick
 - ◆ Piping vibration < Quad Cities



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VY FIV Comparison (cont.)

EPU Maximum Measured Acceleration



Power Ascension Dryer Monitoring

- Purpose: ensure dryer integrity during gradual power increase
 - Pro-actively identify significant increases in MS and dryer FIV
- Approach
- Acceptance criteria
- 115% step 1, outage/inspection in 8 months

Power Ascension Dryer Monitoring (cont.)

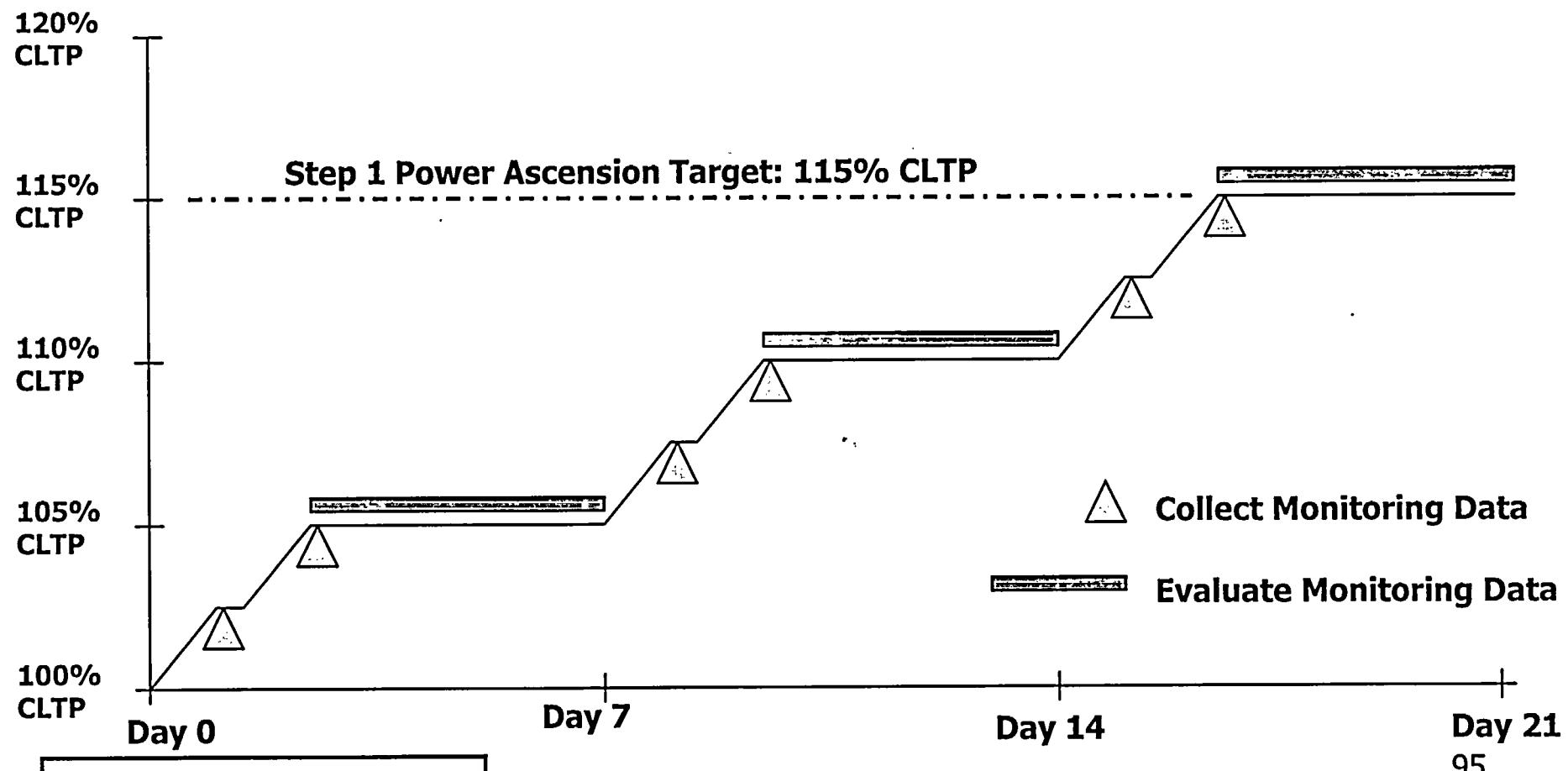
■ Approach

- Take pressure, strain gauge and accelerometer data at approximately 2.5% power test increments, evaluate Level 1 acceptance
- Hold at 5% incremental power levels for 7 days minimum
- Compare data to acceptance criteria
 - ◆ VY EPU response spectrum
 - ◆ Structural analysis ASME fatigue limit
- Moisture carryover monitoring (daily)
- Repeat monitoring for Step 2: 115-120%



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Power Ascension Dryer Monitoring (cont.)



Preliminary Information



Power Ascension Dryer Monitoring (cont.)

- Acceptance criteria

- VY EPU response spectrum
- ASME fatigue limit

Power Ascension Dryer Monitoring (cont.)

- Dryer monitoring acceptance process

Level 1: compare collected strain gauge Fourier spectra to EPU load definition acceptance criteria

- ◆ If less than criteria, dryer structural integrity is confirmed at that power level
- ◆ Otherwise, back down reactor power to an acceptable level and perform Step 2

Power Ascension Dryer Monitoring (cont.)

- Dryer monitoring acceptance process
(cont.)

Level 2: compare acoustic analysis response spectrum to EPU load definition acceptance criteria

- ◆ If less than criteria, dryer structural integrity is confirmed at that power level
- ◆ Otherwise, perform Step 3

Power Ascension Dryer Monitoring (cont.)

- Dryer monitoring acceptance process (cont.)
 - Level 3: run GE structural analysis and compare to stress limit
 - ◆ If acceptable, dryer structural integrity is confirmed at that power level